A STUDY OF PRESENT PRACTICES IN NEW YORK STATE WITH REGARD TO FINE AGGREGATE IN BITUMINOUS CONCRETE

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BITUMINOUS CONCRETE PRODUCERS ASSOCIATION
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A STUDY OF PRESENT PRACTICES IN NEW YORK STATE WITH REGARD TO FINE AGGREGATE IN BITUMINOUS CONCRETE

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A STATEMENT OF THE PROBLEM

Some wide variations exist in the permitted use of artificial sand as the fine aggregate in hot mix bituminous pavements in New York State highways. These variations from District to District range from complete acceptance of the material through decreasing percentages, to complete rejection of artificial sand and the requirement that 100 percent of the fine aggregate be made up of natural sand. At the present time, no basis for the establishment of these specifications seems to be in existence except the judgement of the Engineer.

This wide variation was brought to our attention by the New York Bituminous Producers Association, Inc. in December of 1961. The concern of the producers is primarily a factual one. It is desired to know if these individual specifications are based on technical considerations, properties of local materials or characteristics of the mix.

SCOPE

The scope of this study was expressed in a proposal presented to the New York State Bituminous Concrete Producers Association and explained by the following as a plan of study:

"A PLAN FOR THIS STUDY

Phase (A) To gather information concerning the present practices of various highway organizations in regard to the use of artificial sand.

Phase (B) To determine from the literature what studies have been conducted concerning the use of sand size aggregate resulting from the crushing of quarried rock.

Phase (C) To conduct tests upon bituminous mixes designed with varying percentages of artificial and natural sands making up the fine aggregate content of the mix.

1. Laboratory samples
2. Field samples

Phase (D) To correlate the information obtained in order to evaluate the position of this type of aggregate in the production of asphaltic concrete and its limitations if any.

The phases of this study indicated above are so interdependent that the details of operation are difficult

to establish at this point. Both phase C and D must develop from the information obtained in phases A and B.

It is therefore proposed that phase A and phase B be presently undertaken.

Phase (A) The gathering of information shall be done by correspondence with and interviews with the various New York State Division Engineers and Engineers in corresponding positions in other states.

(1) Information shall be sought concerning:

(a) The permitted use of artificial aggregate.

(b) The type of natural and artificial aggregates available within the area.

(2) Samples of these available aggregate shall be obtained.

(3) Where possible, samples of actual mixes being laid on highways under various conditions of design will be taken and cataloged for later testing.

Phase (B) Concurrent with Phase (A) a library research program will be conducted to examine the literature for information and data resulting from any previous evaluation of sand size aggregate artificially manufactured which may have been made.

Sources: Asphalt Institute
Portland Cement Association
Highway Research Board
Am. Assoc. State Highway Officials, etc.

Upon the completion of the above phases A and B, the continuance of the study into phases C and D can be more completely detailed.

At this point, a detailed proposal for the testing and analysis will be presented as the conclusions from phases A and B."

PROCEDURE

The questionnaire and letter shown in Appendix A was sent to all of the producer members of the New York State Bituminous Concrete Producers Association to determine what percent of artificial sand was being used by their plants. The results of this questionnaire defined the limits of permitted artificial sand from 20% to 100% and located each in their respective Districts (Exhibit 1, Appendix A). A summary of the answers from 21 questionnaires is shown in Appendix A.

As a result of this preliminary investigation, the following approach was undertaken:

A. Interviews with all District Engineers or Materials Engineers were conducted to gather information concerning the present practices of the ten Districts in regard to the use of artificial sand. Emphasis was placed on the philosophy, background, basis and future plans of these specifications.

B. Top mixes, New York State 1-A & 1-AC armorcoat, were sampled from most Districts in order to conduct tests upon these mixes designed with varying percents of artificial and natural sands making up the fine aggregate content of the mix.

C. A survey of current literature was conducted to determine what studies had been made concerning the use

of sand size aggregated resulting from the crushing of quarried rock. Skid resistance and stability were the main objects of most of the reports presented in the following sources:

Asphalt Institute

Association of Asphalt Paving Technologists

Highway Research Board.

INTERVIEWS WITH DISTRICT ENGINEERS

A. Background Material on Practices of DPW Districts Relative to Aggregates for Asphaltic Concrete

The state has six standard mixes: 1A, 1AC, 2A, 2B, 3A, and 5A. For each mix, it designates limits of gradation of aggregate, and asphalt cement content. Fine aggregates (passing 1/8" sieve) are classified as "a", "b", "c", "d", or "e" depending on soundness test results, and (for classes "a" and "b") percent content of kaolin, quartz, and feldspar. Fine aggregates can be clean natural sand, rock sand or rock screenings crushed from approved stone, or slag stone, or combination. Only "a", "b", "c", or "d" fine aggregates are permitted for asphaltic concrete. Mineral filler (the portion of approved aggregates passing No. 200 screen) can be limestone dust, portland cement, diatomaceous earth, flyash or other approved material.

Within the framework of the standard state specifications (1957 Edition) the Districts have considerable freedom to custom-tailor to their local preferences. They can of course operate as desired within the gradation and asphalt content limits for the given standard mixes. They may not relax the State specifications but they are permitted to make them more rigid (unless expressly forbidden to do so). They may designate special mixes: e.g., one district has recently made considerable use of Item 51X, which is a

variation of Item 51, the standard pay item for a 1A mix.

Mix design is not static. Districts have found it desirable from time to time to exercise their given discretionary powers to meet local conditions of aggregate availability, climate, workability of mix and pavement performance. No pavement job is perfect and sometimes a single bad stretch of pavement has been the cause for specification changes applied to many subsequent projects.

The local specification differences which are of concern in this report have to do with the percentages of fine aggregate which is required to be "natural sand". Within the past half dozen years, several of the Districts have established minimum percentages for "natural sand" in surface courses, either directly or indirectly through the process of elimination. There is no restriction on binders. While the State does not completely define "natural sand", it appears to be that mineral aggregate which occurs in its natural state in particles passing 1/8 inch sieve and is not a product of artificial crushing or grinding. Usually "natural sand" is largely composed of quartz and feldspar, in which case it is synomomous with "silica sand". When quarry rock is crushed, the fine particles are called "rock screenings". When "rock screenings" are clean and meet requirements for gradation, they may be properly called "artificial sand". Hence all artificial sand is made from "rock screenings", but not

all "rock screenings" can be properly called "artificial sand", though some people use the two terms as though of identical meaning. In New York State, the most common coarse aggregates come from limestone, trap rock, dolomite and sandstone, hence these are the sources also of "rock screenings" and "artificial sand". Obviously, the sandstone would yield "rock screenings" high in silica and could be classed as "a" or "b", whereas "rock screenings" from the other sources would of necessity be classed as "c", "d", or "e".

B. Comments of Individual Districts

In the interviews with District Engineers and Materials Engineers, three definite factors were given for establishing minimum natural sand minimum percentages: (1) skid resistance, (2) gradation control, (3) workability.

District #7 (Watertown) reported that several years ago it had experienced extreme slipperiness on Route #11. Addition of a Kentucky rock asphalt surface treatment (highly recommended in many parts of the United States for de-slicking pavements) only worsened the slipperiness. Further experimenting culminated in substantial changes in mix design as follows: (1) mineral filler content was reduced; (2) asphalt content was reduced; (3) silica sand was substituted for practically all of the sand-size aggregate which previously had been rock screenings. These changes were incorporated into Special Item 51X now widely used by this District. Item 51X does

not mention "natural sand". It says that "...at least 35% of Top Course shall consist of sand whose Quartz and Feldspar content shall be at least 75%, and the gradation shall conform with the N. Y. State Specification for concrete sand...." Since Item 51X calls for 40% of the mixture weight to be minus 1/8", in effect 35/40 or 87-1/2% of the fine aggregate (including mineral filler) is required to be silica sand. (It should be noted that sandstone rock screenings would be permissible under this specification. Usually, however, sandstone screenings fail to meet other tests, hence for all practical purposes Item 51X calls for natural sand to the exclusion of nearly all of the artificial).

In District #8 (Poughkeepsie), for about five years, natural sand has been required as a means of quality control-specifically control of gradation and impurities such as clay and organic material. The District is very conscious of the distinction between "rock screenings" and true "artificial sand". The District feels that very few of the producers are capable of producing truly graded, clean "artificial sand" and instead the bulk of the producers want to use the entire minus 1/8" fraction of the crushed quarry rock in the mix, with the result that the gradation of the fines fluctuates from day to day, too rapidly to compensate by adjustment of the asphalt content. Natural sand, on the other hand, has been blessed by Nature with more consistent gradation resulting in better uniformity in the final mixture.

The District feels that the minimum-maximum limits of the State specifications are too far apart, hence quality control is best assured by the use of natural sand. In addition, the District feels that even with true "artificial sand", the mix is less workable than with natural sand; "artificial sand" particles are more elongated than the characteristic cubical shape of natural sand. However, this harshness is much less important to the District than the matter of gradation, as indicated by the fact that one or two plants are permitted to use 50% artificial sand where they have shown satisfactory evidence of their ability to produce true "artificial sand". The district points out that natural sand deposits are plentiful in the area, and hence costs no more than artificial sand. The District is of the opinion that there is a ready market for "rock screenings" and "artificial sand" for purposes other than in asphaltic concrete; however, this opinion is not shared by at least one producer, who also feels that he can supply true "artificial sand" cheaper than "natural sand" and thereby save dollars to the taxpayer.

District #9 (Binghamton) agrees with District #8 as to the nature of the shortcomings of "rock screenings". In this district, much of the available quarry rock is sandstone, hence the rock screenings are silica materials, but do not satisfy the other requirements for class "a" or "b" sands. For major roads, the District requires 100%

"a" or "b" sands; for secondary roads, it requires a minimum of 70% "a" or "b" sands but would like to be permitted by Albany headquarters to require 100% for secondary roads, too. The District readily agrees that the cost of natural sand is greater than "rock screenings" since there is practically no natural sand within the District. But it defends its policy vigorously as necessary to obtain acceptable quality in its asphaltic mixes.

District #2 (Utica) adopted a 50% natural sand requirement only a few months ago. It agrees with Districts #8 and #9 as to the lack of consistency of gradation of artificial sands, and also the harshness of the resulting mixes("unworkable"). In general, this District seems less positive in the matter than Districts #8 and #9.

District #5 (Buffalo) has no restriction on "artificial"sand" in the 1A mixes, but restricts to 20% its use on the less common 2A (urban areas) and 2B (bridge decks) mixes. District officials were not sure of the origin of this requirement of some five years standing, but felt that it must have been due to some fault in gradation which was troublesome with the finer 2A and 2B mixes but not with the 1A mixes. Complicating the picture is the fact that in the southern part of the District, the natural sands are deficient in certain size fractions, notably the #80 size, which thus needs some artificial sand blended with it to correct this deficiency.

District #6 (Hornell) has no restrictions on the use of "artificial sand" but it is in the peculiar position of having had little experience with artificial sand. The reason for this is that there are no commercial rock quarries in the District (the native sandstones being under deep overburden) hence all crushed stone must be imported from other Districts. Since natural sand pits are located much closer than the rock quarries, asphalt concrete producers have always used natural sand voluntarily, because of the savings in freight cost.

District #1 (Albany), #4 (Rochester) and #3 (Syracuse) have no restrictions on "artificial sand" although District #3 is not wholly satisfied with the gradation.

District #10 (Babylon) has no restriction on the use of artificial sand, but have had little experience with the use of it, due the abundant supply of natural sand. It was implied that they would not like to use 100% artificial sand, and, in the event it was used, special quality control would be exercised.

The above information appears in tabular form in Table #1.

TABLE #1

DISTRICT	# 6 Hornel	#7 Watertow
Does Distri sand?	No	Yes
What percen	100%	13%
How long ha		5 years
Reason for		Slipperiness
Comments	Natural sand used voluntarily cheaper	
Are artifici		
Are rock scr permitted in		
Are rock scr		
Is artificia locally?	No	Yes
Is natural s locally?	Yes	Yes but ofter lacks require silica
Is washing o		No
Does Distric of asphalt c	High	Low
Does Distric of minus #20	Low	Low
Is skid resi problem?	No	Yes, bleedin and polishin
Has "polishi	No	Yes, acute p blem but sol by silica sa
What types o	None locally import limestone & dolomite	Limestone
How does Dis	Experience	Experience
Do producers filler to ge	No	Only for 1AC Armor Coat

TABLE #1

COMMENTS OF INDIVIDUAL DISTRICTS

DISTRICT	# 1 Albany	# 2 Utica	# 3 Syracuse	# 4 Rochester	# 5 Buffalo	# 6 Hornel	#7 Watertown	#8 Poughkeepsie	#9 Binghamton	#10 Babylon
Does District restrict the use of artificial sand?	No	Yes	No	No	Yes	No	Yes	Yes	Yes	No
What percent of sand may be artificial?	100%	50%	100%	100%	100% on Type 1A 20% 2A and 2B	100%	13%	0%	30% second rds. 0% on Major rds.	Allowed but 100% not used
How long has restriction existed (years)?		3 mo.			3-4 years		5 years	5 years	2 years	
Reason for restriction		more workable mix			Not sure, due to poor gradation		Slipperiness	Wide day-day variation in gradation	Same as #8	District would not like to see 100% artificial sand in mix. 100% natural and 50-50 blends are used by choice of producers.
		better gradation in sand size						Mix is harsh using artificial	Mix is harse using artificial	
		gives proper amounts [illegible] of the sieves								
Comments						Natural sand used voluntarily cheaper		A few plants are permitted 50% artificial	Require "a" or "B" sands on major roads, a,b, or c on secondary.	
Are artificial screenings poorly graded?			Yes, high on 8-20; low on 20-80					Yes, elongated		Yes, large gap between #20 and #200
Are rock screenings (except limestone) permitted in P. C. Concrete?			No	No	Yes			No	No	No
Are rock screenings poorly shaped?			Yes, elongated		Not known			Yes	Yes	
Is artificial sand reasonably plentiful locally?	Yes	Yes	Yes		Yes	No	Yes	Yes, surplus	Yes	No, imported when used.
Is natural sand reasonably plentiful locally?	No	Yes		Yes, but skip graded	Yes	Yes	Yes but often lacks required silica	Yes	No, most must be hauled from Dist #2 and #8	Yes, it is exported to other Districts.
Is washing of crushed aggregate required?				No	No		No		Yes, sandstone No, limestone	No
Does District tend toward high or low limit of asphalt content?			High	High	High	High	Low	Low	High	High
Does District tend toward high or low limit of minus #200?				High	Low	Low	Low	Low	High	
Is skid resistance a particularly acute problem?		are getting more skid resistance [illegible]ments	No	No, no bleeding with only 1% voids	No	No	Yes, bleeding and polishing	No	No	No
Has "polishing" of aggregate been a problem?			No	No	No	No	Yes, acute problem but solved by silica sand.	No	No	Noted difference between limestone and traprock
What types of stones are used?	Limestone, Gray Wacky Quartzite	Limestone	Mostly limestone some dolomite	Mostly limestone some dolomite		None locally import limestone & dolomite	Limestone	Limestone, trap	Sandstone, Limestone	Limestone and traprock
How does District determine % of A. C. To use?	State Spec.	State Spec.	Experience	Experience	Experience	Experience	Experience	Experience	Experience	% retained & passing 1/8" sieve.
Do producers usually need to add mineral filler to get gradation specified?	No	No		Yes		No	Only for 1AC Armor Coat	No	Yes	Yes

TECHNICAL EVALUATION OF VARIOUS SOURCES

Marshall Compaction equipment was taken to most districts, and an average of nine marshall specimens were compacted of top mixes from the pug mill of each plant. Six by eight inch rectangular specimens were also compacted by a modified Hubbard-Field procedure in hope to be able to run laboratory skid tests on the mix.

The laboratory skid tests were not run on these specimens, but saved in the event of future testing. The laboratory compaction techniques have not been perfected to reproduce the actual rolled pavement surfaces. The surface texture and densities of the specimens did not simulate the actual conditions. At most only relative values of skid coefficient could be expected from this approach.

The most valuable data comes from the Marshall design test procedures, where stability, flow, and percent voids can be analyzed.

It is possible to attain a high degree of control in an asphalt laboratory where the quantity of each ingredient of the mix formula is known to be accurate, and hence specific comparisons can be made. In an asphalt hot mix plant, however, the control is much less exact. Hence only the most general conclusions can be drawn from the data obtained.

LABORATORY RESULTS

Conclusions

% Voids. The most significant conclusion of the laboratory analysis is the low percents of air voids in those mixes with the natural sands. Marshall design criteria calls for 2% - 6% with 4% as optimum. Most of the specimens compacted with the fifty blow Marshall procedure had a void content below 4%. Those mixes with natural sand had void contents from 0.5% to 2.5%. The low void content is a function of the asphalt content, gradation and workability. The more workable mixes will compact readily with little resistance to compaction. This condition is primarily a function of the particle shape and gradation of the aggregates. The gradation range is fixed and the great difference lies in the shape of sand particles. The low void content is a definite disadvantage in the surface courses, as any traffic compaction or thermal expansion will introduce bleeding and rutting in the pavement. This was observed during Marshall compaction of some of the rich mixes. The bleeding asphalt would have a tendency to creep up the sides of the collars.

The artificial sand mixes were more harsh, and resisted compaction enough to allow the proper void content. We cannot say this exists in the pavement, but feel the fifty blow Marshall is comparable to field compaction. In

no case did we notice any evidence of aggregate crushing or breaking during compaction.

<u>% Voids Filled</u>. In most cases those mixes with natural sand had a high % voids filled, which is accompanied with the low void content. The Marshall criteria is 75-85 of the aggregate voids filled with asphalt cement. Most of the natural sand mixes had a percent voids filled well in the 90's.

<u>Marshall Stability</u>. Most of the Marshall Stabilities ran higher with the artificial sand, but not significantly higher. This could be caused by greater interlocking of the aggregates. There is no recommended upper limit for Marshall Stabilities; however, extremely high stabilities can be a disadvantage as it has a tendency to make the pavement too rigid. Consequently, any movement in the substrata will cause cracks in the surface.

<u>Flow</u>. The Marshall flow is a measure in 1/100 of an inch of the deformation of the specimen at maximum load. This also is a relative value of rigidity in the mix. The maximum recommended by the Asphalt Institute for 100 psi tires is 20 with no stipulation as to a minimum. All of the natural sand mixes had higher flow values than the artificial sand mixes thus showing a greater tendency of the natural sands to move and reorient before a permanent yield of the compacted mix. Excessive flow in a mix is a

definite indication that the mix will groove or develop ruts under traffic load. Flow values between 13 and 20 are assets to any pavement, thus allowing it to deform without cracking. The natural sand mixes had flow values in a range from 17 to 24 with an average of 19.7. This is very close to the upper limit to be accepted without further study.

No recommendation can be based on these few tests as to the use of natural or artificial sands or a combination of the two. However, a definite trend is prevalent, and more extensive testing of this nature should be conducted at each plant in order to make adjustments in the mix. Due to the wide spectrum of local material that exists in New York State, it appears feasible that these materials can be used in asphalt concrete mixes, provided each element will satisfy the quality control established.

A summary of the laboratory results from Appendix B is shown on the following pages, 19 and 20.

1-AC Armorcoat N. Y. State

Location	Cairo	Catskill	Cropseyville	Prospect	Fort Herkimer	Oriskany Falls	Buffalo	Watertown
District	#1			#2			#5	#7
Plants Visited	1	2	3	4	5	6	7	8
MIX CHARACTERISTIC								
% Artificial Sand	100	100	100	100	50	50	50	13
% Passing 1/8" Sieve	51.5	64.2	58.2	550	55.5	46.2	57.0	50.3
% Asphalt	7.3	6.7	6.75	6.7	6.2	7.3	7.0	7.2
Compacted Specific Gravity	2.39	2.36	2.31	2.31	2.40	2.39	2.35	2.39
% Air Voids	1.7	4.0	4.1	4.6	1.8	0.5	2.5	1.0
% Voids Filled	98	78	78	77	89	97	85.7	95
Unit Weight #/ft^3	149	147	144	144	150	149	146.5	149
Marshall Stability	2300	1854	1845	1630	2100	1800	1715	1340
Flow	18	13	11	12	17	19	19	19

Location	South Beth	Oriskany	Penfield	Buffalo	Hornell
District	#1	#2	#4	#5	#6
Plants Visited	1	2	3	4	5
MIX CHARACTERISTICS					
% Artificial Sand	0	50	50	50	0
% Passing 1/8" Sieve	40	47.4	37.5	45.8	57.3
% Asphalt	6.5	6.3	6.7	7.0	6.6
Compacted Specific Gravity	2.37	2.38	2.46	2.37	2.36
% Air Voids	2.9	2.3	1.2	1.7	2.5
% Voids Filled	85	86.5	94	89.5	86
Unit Weight #/ft^3	148	148.5	153.5	148	147
Marshall Stability	1115	1510	1604	1468	1615
Flow	13	17	24	23	14

REVIEW OF CURRENT LITERATURE

The three most important controversial arguments as to the use of artificial sand over natural sands are (1) economics (2) skid resistance (3) workability.

Economics. The economics of the natural sands depend primarily upon the available sources and the transportation cost. In Appendix C is a list of New York State Department of Public Works approved sources of concrete sands. The sands are classified in the a, b, c, and d types which are acceptable for asphaltic concrete. Most district engineer's offices have available for distribution copies of approved sources of fine aggregate for their district. These lists change quite frequently; therefore, it is recommended that a producer in need of this material procure a more recent list from his district engineer's office.

Maps of New York State showing some quarry locations and fine aggregate natural sand sources are included in the cover page. The Stone Quarry map shows both potential and operating sources of artificial sands. These are available through the New York State Department of Public Works.

Skid Resistance. Excerpts from the First International Skid Prevention Conference held in September 1958 at Charlottesville, Virginia, are referred to when pertaining to the use of natural and artificial sands.

Results of Trial Mixes. Workability is associated with the voids analysis and stability. Data from trial laboratory prepared mixes of varying percentages of natural sands are presented. This data was taken from the publications of the Association of Asphalt Paving Technologists and the Highway Research Board.

Four references are reviewed as the most important to this study. A list of the references reviewed are in Appendix C. These references were recommended by Mr. Charles R. Foster, NBCA's Coordinator of Research and Miller-Warden Associates, Consultants, Raleigh, North Carolina.

FINDINGS

At the beginning of this study, one of the investigators expected that the matter of slipperiness would turn out to be the dominant factor behind the restrictions on the use of artificial sand. Largely as a result of tests and recommendations made by Virginia, at least three other states (Kentucky, Tennessee and Georgia) have recently restricted the use of artificial sand to curb slipperiness arising from the polishing of the relatively soft limestone particles. It is interesting to note that still more recently, Virginia has conceded that subsequent tests revealed no significant superiority of natural sand over artificial sand in the matter of slipperiness.

However the study has revealed that only one District (#7) is restricting artificial sand due to slipperiness. It is to be noted that on its worst case of slipperiness the District topped off the pavement with some four pounds of iron mine tailings per square yard broadcast on the surface after the breakdown rolling. It is interesting to speculate whether this surface treatment might not have been responsible for the curing of the slipperiness rather than the substitution of natural sand for artificial.

But the chief reason for the restrictions on artificial sand has turned out to be the unsatisfactoriness of the gradation. Since the State specifications establish

gradation limits, it may be difficult to understand why gradation control cannot be maintained under these limits. The answer to this as given by the Districts is that for any given project a "job mix" is worked out built around the gradation of the source or sources of the aggregate to be used; but if this aggregate gradation is erratic, the final product will not be uniform. The investigators agree with this argument but feel that this does not automatically point to the necessity of restricting of "artificial sand", but only to the restricting of "rock screenings". It would seem reasonable that _if_ an individual producer of artificial sand _can_ produce consistent gradation as desired, then it would be in the best interests of the State of New York to permit that producer to use that artificial sand; this action could hardly be justification for a charge of favoritism. The previous sentence was predicated on the supposition that there does exist suitable equipment and procedures for producing a consistently true "artificial sand"; the investigators have not studied this question, but would recommend such a study as the next phase, now that the policies of the several Districts are known.

As to the third factor cited as reason for restricting the use of "artificial sand" - workability - the investigators have not analyzed this question either, and recommend it for study. Off-hand, it seems strange that after many years of experience using artificial sand, we should only recently have

awakened to the fact of its unworkability; but such may be the case. In any case, it should be a relatively simple matter to compare workabilities of natural sand mixes vs. artificial sand mixes, preferably on an actual pavement project and with the cooperation of contractor-producer and District representatives.

The investigators are not so naive as to assume that some experiments along these lines have not already been made within the Districts; but the fact is that some of the producers are convinced that artificial sand is not inferior to natural sand. The investigators have met with good cooperation by District officials throughout the study thus far, and they believe that they would continue to enjoy the cooperation of the Districts in the joint experiments as previously mentioned. It is recognized that it is the prerogative of the District, not the producers, to make decisions in such matters but that obviously the District stands to gain if decisions can be made more palatable or at any rate more understandable to the producers.

Technical Evaluations. Workability has been defined as a condition of the mix that permits it to compact and handle easily. Good workability has been associated with those mixes having 50 to 100 percent natural sand. It is quite reasonable to expect rounded particles to compact easier than sharper, elongated ones. The voids analysis showed this to be quite true. However, there is a limit to how dense an asphalt concrete pavement should be compacted. This has been established at 4% air voids. Most of the natural sand mixes had void contents below 4%. The artificial sand appeared to resist compaction enough to provide for 4% air voids.

The percent aggregate voids filled with asphalt cement was considerably higher among the natural sand mixes. The designs call for 80% voids filled. Most of the natural sand mixes were well in the 90's. This is an undesirable characteristic of a too workable mix.

The average Marshall Stability ran higher with the artificial sand mixes than the natural sand mixes. The higher stabilities is best explained by the keying or interlocking of the aggregates.

Higher Marshall flow values were characterized by the natural sand mixes. This is further evidence that the particles are freer to move in the natural sand mixes due to the particle shape. This would lead one to expect more grooving in natural sand mix. However, a certain amount

of movement or deflection is necessary for flexible pavement particularly in the top courses.

Library Research. In the majority of the investigations conducted in the laboratory and in the field, the primary objections were to determine relative differences in the types and gradations of various aggregates. These types were correlated as to their skid resistance and stability qualities.

[1]Virginia conducted probably the most comprehensive study on their pavements and overlays. They held the First International Skid Prevention Conferense in 1958. The Research reports presented at this conference concluded that slipperiness was not a function of the sand size aggregates but primarily a factor of the polishing characteristics of the coarser aggregates. It was found that a sand paper finish of a silica sand mix, which is highly resistant to abrasion, would hold or carry thin films of water that cause a high speed tire to aquaplane. The more open or rough textured surface allows the water to drain around the surface particles and thus provides a more jagged surface to resist skidding. As a result of this hypothesis, polishing coarse aggregates, such as limestone and dolomite, have been restricted from the top courses.

[2]Marshall and triaxial compression tests were run on prepared trial mixes of varying percents of natural sand. These tests concluded that higher stabilities were

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1. Skid Resistance - Appendix C
2. Results of Trial Mixes - Appendix C

not a result of high densities. The natural sands produced the higher densities. The higher strengths of the artificial sand mixes were quite pronounced in the triaxile tests running usually 125 pounds above the natural sand mixes which was approximately 25% of testing range.

The voids analysis showed both natural and crushed sand to be very similar. This was primarily due to the fact that the crushed particles were the same aggregate type and had the same specific gravity as the natural sands.

RECOMMENDATIONS

As a result of these studies, the following recommendations are proposed:

1. That the New York State Bituminous Concrete Producers Association continue the present study by:
   (a) An investigation of the feasibility of attaining consistent quality (including gradation) in the production of artificial sands in existing aggregate plants in this state. This study should include equipment and techniques to produce desired and uniform gradations in manufactured sands. The shape and physical structure of the graded particles as well as aggregate classification should be included in this study.
   (b) An investigation of the relative workabilities of natural sand mixes versus artificial sand mixes.
   (c) An investigation of the relative skid resistance of natural sand mixes versus artificial sand mixes.
   (d) An extension of the stability/flow/void testing begun under the present study.
2. That the New York State Bituminous Concrete Producers Association, the New York State Department of Public Works, The Asphalt Institute, and Rensselaer Polytechnic Institute jointly sponsor a periodic "short course" in asphalt technology for the benefit of plant personnel.

This short course might consist of five all-day sessions in some off-season part of the year.

3. That the New York State Bituminous Concrete Producers Association, the New York State Department of Public Works, The Asphalt Institute, and Rensselaer Polytechnic Institute jointly sponsor a separate "short course" in asphalt technology for the benefit of plant inspectors and materials engineers from all districts of New York State. These men would be made aware of the most recent thinking on mix design, the best approach to quality control at the plant and on the road. At such meetings recommendations could probably be made which might lead to more uniform requirements throughout the state.

4. A Research and Development program of the New York State Bituminous Concrete Producers Association, Inc. should be organized under their control and jurisdiction. This program could propose studies of other problems that are of common interest to each producer, as well as provide advice and counsel for individual problems. Individual problems could be solved in a consulting capacity and thus could be independently financed.

APPENDIX A

Evaluation of Questionnaires

Preliminary Investigation

APPENDIX A

The following letter and questionnaire was sent to all of the producer members of the New York State Bituminous Concrete Producers Association on April 5, 1962.

Dear (   ):

Concerning a study of practices in regard to the materials used in asphaltic concrete being made for the New York Bituminous Concrete Producers Association, we should like your cooperation in gathering certain information.

The basic reason for this study appears to be a variation in the requirements imposed by the District Engineers of the various districts in New York State. We are interested in attempting to analyze these requirements imposed and determine whether or not there are logical reasons for the variation in the type of sand sized aggregate which is allowed.

The first information we must have is just what is the extent of the variations that the producers find exist in the various districts of the State. We would therefore appreciate it if you would fill out and return the enclosed questionnaire concerning the practice that you have encountered in doing asphaltic concrete paving in the various district of New York State.

Thank you for your cooperation in this matter.

Very truly yours,

The following is a tabulation of answers by districts received from 23 questionnaires.

QUESTIONNAIRE

Please indicate the answers to the following three questions in the tabulation below.

(a) Do you find that sand size aggregate in asphaltic concrete is restricted to only natural sand?

(b) If the answer to (a) is no, do you find that 100 per cent substitution of artificial sand is permitted?

(c) If the answer to (b) is no, what per cent of the sand size aggregate is allowed to be artificial sand?

DISTRICT 1

Questionnaire No.	(a)		(b)		(c)	Comments
	yes	no	yes	no	% Art.	
1.		x	x		100%	
2.		x	x		100%	
3.		x	x		100%	
4.		x	x		100%	
5.		x	x		100%	

DISTRICT 2

Questionnaire No.	(a) yes	(a) no	(b) yes	(b) no	(c) %Art.	Comments
1		x	x in base	x in top	50%	
3		x	x		100%	We have heard that in certain instances this practice has been modified somewhat.
18		x	x		100%	In base
		x		x	50%	50% of -1/2" material must be natural sand to increase skid resistance and to make a tougher pavement.
23		x		x	50%	

DISTRICT 3

Questionnaire No.	(a) yes	(a) no	(b) yes	(b) no	(c) %Art.	Comments
6		x	x		100%	Providing gradation equals Specs.
				x	50%	For Items 52A and 52B.
22	x					

DISTRICT 4

Questionnaire No.	(a) yes	(a) no	(b) yes	(b) no	(c) %Art.	Comments
7		x	x		100%	
8		x	x		100%	
9		x	x		100%	
23		x	x		100%	

DISTRICT 5

Questionnaire No.	(a) yes	(a) no	(b) yes	(b) no	(c) %Art.	Comments
8		x	x			Understanding is that 80% natural sand is required in densely graded mixtures. Gradation requirements for Type 2A or 2B fine aggregate cannot be met with artificial sand.
10		x		x	20%	Item 52
		x	x		100%	Item 45 SX, 51 52 binder.
11		x	x		100%	

DISTRICT 6

Questionnaire No.	(a) yes	(a) no	(b) yes	(b) no	(c) %Art.	Comments
11		x	x		100%	
22						

DISTRICT 7

Questionnaire No.	(a) yes	(a) no	(b) yes	(b) no	(c) %Art.	Comments
3		x	x			We have heard that in certain instances this practice has been modified somewhat.

DISTRICT 8

Questionnaire No.	(a) yes	(a) no	(b) yes	(b) no	(c) %Art.	Comments
1		x	x		100%	It is my understanding that some plants in Dist. 8 are required to use <u>some Natural</u>.
12						Since opening in July 1960 we have not had occasion to request use of other than Natural Sand.
13		x	x		100%	Unconfirmed reports say we may have to blend in the future.
14		x	x			Allows use of crushed hardheads.
15		x		x	50%	Wearing and top courses.
	x	x	x		100%	Binder and base courses.
						State would prefer all natural sand but does permit above.
23		x		x	50%	Only natural sand can meet gradation.

DISTRICT 9

Questionnaire No.	(a) yes	(a) no	(b) yes	(b) no	(c) %Art.	Comments
1		x			65%	Assume he means 65% natural sand required. Did not check (b) - assume no.
2		x		x	30%	
3						We find that our Type A Artificial Sand is effectively barred from use in District 9.
14	x			x	30%	District 9 does not allow the use of crushed gravel hardheads.
16		x		x	30%	
17		x		x	30%	
18	x					Gradation not sat., with broken limestone natural sand used.

DISTRICT 10

Questionnaire No.	(a) yes	(a) no	(b) yes	(b) no	(c) %Art.	Comments
19		x	x		100%	Mt. Vernon Plant uses natural sand only. Baldwin, L. I. uses 25% Stone Screenings. We understand other plants on L. I. accomplish same job with 100% artificial sand.
20		x	x		100%	

SUMMARY (23 Reports)

District 1 - <u>No problem</u> permits 100% Artificial Sand.

District 2 - Requires 50% in Top course.
Allows 100% Artificial Sand in base course.

District 3 - Permits 100% Artificial Sand in base.
Requires 50% Natural Sand in 52A and 52B.

District 4 - <u>No problem</u> permits 100% Artificial Sand.

District 5 - Allows only 20% Artificial Sand in Item 52.
Allows 100% Artificial Sand in base and binder.
Statement made that gradation requirements cannot be met for 2A or 2B with Artificial Sand.

District 6 - <u>No problem</u> permits 100% Artificial Sand.
One report says Natural Sand 100% (22)

District 7 - <u>No problem</u> except hearsay that in <u>some</u> instances this has been modified.

District 8 - Reports not uniform:

3 report 100% Artificial Sand permitted.
1 reports 50% Natural Sand required in top.
1 reports rumor that plants will have to blend in the future.

District 9 - Maximum of 30% Artificial Sand permitted.
Statement that <u>gradation</u> not satisfactory with Artificial Sand.

District 10 - No problem   100% Artificial sand permitted.

3 No problem. 100% Artificial Sand allowed

3 50% Natural Sand required.

1 70% Natural Sand required.

1 80% Natural Sand required.

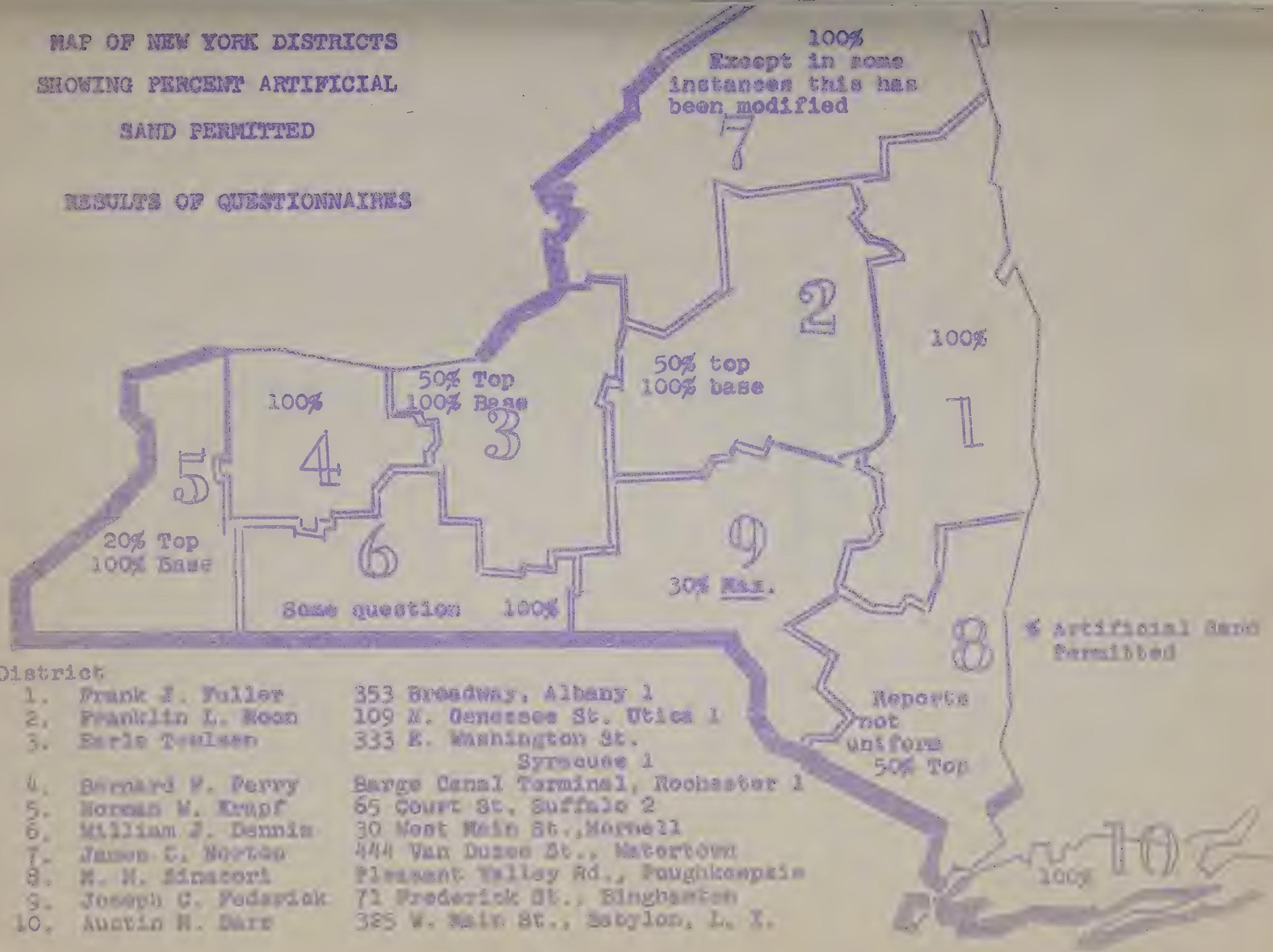
2 Seem to be variations.

MAP OF NEW YORK DISTRICTS

SHOWING PERCENT ARTIFICIAL

SAND PERMITTED

RESULTS OF QUESTIONNAIRES



District

1.	Frank J. Fuller	353 Broadway, Albany 1
2.	Franklin L. Moon	109 N. Genesee St. Utica 1
3.	Earle Teelsen	333 E. Washington St. Syracuse 1
4.	Bernard F. Perry	Barge Canal Terminal, Rochester 1
5.	Norman W. Krapf	65 Court St, Suffalo 2
6.	William J. Dennis	30 West Main St.,Hornell
7.	James C. Norton	444 Van Duzee St., Watertown
8.	M. H. Sinacori	Pleasant Valley Rd., Poughkeepsie
9.	Joseph C. Federick	71 Frederick St., Binghamton
10.	Austin N. Darr	325 W. Main St., Babylon, L. I.

APPENDIX B

Technical Evaluations

AGGREGATES & MIXTURES

Callanan Road Improvement Company

PROJECT

SOURCE OR LOCATION OF SAMPLE South Bethlehem, New York DATE RECEIVED 7/12/62

TAKEN BY W. Byrd LaPrade

REPORTED TO DATE REPORTED

ANALYSIS

Laboratory No.	1-A Mix N. Y. State					
Sample No.	40% Artificial Sand					
Class Aggregate	Sp. Gr. Agg. 2.71					
Passing						
" 1/2	100.0					
" 1/4	75.0					
" 1/8	40.0					
" 20	27.7					
" 80	5.1					
" 200	2.0					
"						
"						
% of Bitumen	6.5					
Marshall Stability	1115	Probable error ± 35#				
Flow	13					
Loss by Degradation						
Specific Gravity	2.37					
Percent Voids	2.9					
Percent Voids filled	85					
Weight Per Cu. Ft.	148					
Remarks						

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Speci-men No. A	Asphalt Cement % B	Thickness in C	Wt. - Grams IN AIR D	Wt. - Grams IN WATER E	Vol. F (D-E)	Sp. Gr. Act. G D/F	Sp. Gr. Theo. H *	AC by Vol. - % I BG/Sp.Gr. of AC	Voids - percent J (100-100G/H)	Voids - percent K I/I+J	Unit Wt. Total Mix L G x 62.4	Stability - lb Measured M	Stability - lb Converted N	Flow O
1 A		2 3/4	1279	742	537	2.38						1470	1265	16
B		2 1/2	1205	701	504	2.39						1530	1530	12
C		2 5/8	1287	749	538	2.39						1620	1510	13
2 A		2 9/16	1227	712	515	2.38						1360	1310	13
B		2 7/16	1172	676	496	2.37						1180	1230	13
C		2 5/8	1251	723	528	2.37						1260	1170	12
3 A		2 1/2	1186	684	502	2.37						1060	1060	12
B		2 7/16	1163	669	494	2.36						910	950	12
C		2 9/16	1206	695	511	2.36						1170	1120	12
4 A		2 3/8	1129	653	476	2.37						1070	1170	13
B		2 5/16	1094	631	463	2.37						920	1050	12
C		2 5/8	1061	594	467	2.37						1040	1120	15
				Avg.		2.37	2.44		2.9	85	148		1115	13

Computed by: | Checked by:

AGGREGATES & MIXTURES

District #1

Peckhan Industries

PROJECT

SOURCE OR LOCATION OF SAMPLE Cold Mix
Cairo, New York

DATE RECEIVED 6/22/62

TAKEN BY W. Byrd LaPrade

REPORTED TO Westly Butts (Plant Manager)

DATE REPORTED

ANALYSIS

Laboratory No.	1-AC Mix New York State					
Sample No.	100% Artificial Sand Sp. Gr. 2.72					
Class Aggregate						
Passing						
# 1/2	100.0					
# 1/4	85.2					
# 1/8	51.5					
# 20	28.7					
# 80	9.2					
# 200	3.7					
#						
#						
% of Bitumen	7.3					
Marshall Stability	2300	Probable error ± 45#				
Flow	18					
Loss by Decantation						
Specific Gravity	2.39					
Percent Voids	1.7					
Percent Voids Filled	98					
Weight Per Cu. Ft.	149					
Moisture						

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Specimen No. A	Asphalt Cement % B	Thickness in C	Wt. - Grams IN AIR D	Wt. - Grams IN WATER E	Vol. F (D-E)	Sp. Gr. Act. G D/F	Sp. Gr. Theo. H *	AC by Vol. - % I BG/SpGr. of AC	Voids - percent J (100-100G/H)	Voids - percent K I/I+J	Unit Wt. Total Mix L G×62.4	Stability - lb. Measured M	Stability - lb. Converted N	Flow O
1 A		2 3/8	1145	662	483	2.37						2000	2180	17
B		2 1/4	1081	628	453	2.39						2040	2430	19
C		2 1/4	1047	605	442	2.37						2080	2480	18
2 A		2 1/8	980	539	441	2.38						1720	2270	17
B		2 3/8	1123	654	474	2.38						2080	2270	18
C		2 3/8	1062	616	446	2.38						1900	2380	17
3 A		2 1/8	1023	590	433	2.37						1960	2580	20
B		2 1/8	1001	590	411	2.43						1560	2060	17
C		2 1/4	1092	645	447	2.45						2150	2560	19
4 A		2	958	556	402	2.39						1490	2190	18
B		2 1/8	996	574	422	2.37						1380	1820	17
				Avg.		2.39	2.43		1.7	98	149		2300	18

Computed by: | Checked by:

AGGREGATES & MIXTURES
District #1

Fitzgerald Brothers Construction Co., Inc. 504 Broadway, Troy, N. Y.
John D. Farrell
PROJECT

SOURCE OR LOCATION OF SAMPLE Troy, New York DATE RECEIVED 6/19/62

TAKEN BY W. Byrd LaPrade

REPORTED TO DATE REPORTED

ANALYSIS

Laboratory No.	1-AC Mix N. Y. State					
Sample No.	100% Gray Wacky Quartzite					
Class Aggregate	Sp. Gr. 2.71					
Passing						
" 1/2	100.0					
" 1/4	94.7					
" 1/8	58.2					
" 20	26.5					
" 80	11.5					
" 200	6.2					
"						
"						
% of Bitumen	6.75					
Marshall Stability	1845	Probable error 75#				
Flow	11					
Loss by Decantation						
Specific Gravity	2.31					
Percent Voids	4.1					
Percent Voids Filled	78					
Weight Per Cu. Ft.	144					
Moisture						

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Speci-men No. A	Asphalt Cement % B	Thickness in C	Wt. - Grams In Air D	Wt. - Grams In Water E	Vol. F (D-E)	Sp. Gr. Act. G D/F	Sp. Gr. Theo. H *	AC by Vol. - % I BG/SpGr. of AC	Voids - percent J (100-100G/H)	Voids - percent K I/I+J	Unit Wt. Total Mix L G×62.4	Stability - lb Measured M	Stability - lb Converted N	Flow O
1 A		2 7/16	1128	640	488	2.31						2040	2120	12
B		2 1/2	1182	666	516	2.30						2000	2000	11
C		2 5/16	1092	619	474	2.31						1800	2050	10
2 A		2 1/2	1101	619	482	2.30						1420	1420	10
B		2 1/4	1037	590	447	2.32						1660	1975	10
C		2 1/4	1048	584	464	2.31						1270	1510	12
				Avg.		2.31							1845	11

Computed by: | Checked by:

AGGREGATES & MIXTURES

Peckhan Industries

PROJECT

SOURCE OR LOCATION OF SAMPLE Cold Mix
Cairo, New York

DATE RECEIVED 6/22/62

TAKEN BY W. Byrd LaPrade

REPORTED TO

DATE REPORTED

ANALYSIS

Laboratory No.	1-AC Ar	morcoat	Mix N. Y	. State			
Sample No.	100% Ar	tificial	Sand				
Class Aggregate	Sp. Gr.	2.72					
Passing							
" 1/2	100.0						
" 1/4	90.0						
" 1/8	64.2						
" 20	33.2						
" 80	11.1						
" 200	3.7						
"							
"							
% of Bitumen	6.7	(85-100	Pen)				
Marshall Stability	1854	Probabl	e error ± 55#				
Flow	13						
Loss by Decantation							
Specific Gravity	2.36						
Percent Voids	4.0						
Percent Voids Filled	78						
Weight Per Cu. Ft.	147						
Moisture							

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Specimen No. A	Asphalt Cement % B	Thickness in C	Wt. - Grams In Air D	Wt. - Grams In Water E	Vol. F (D-E)	Sp. Gr. Act. G D/F	Sp. Gr. Theo. H *	AC by Vol. - % I BG/SpGr. of AC	Voids - percent J (100-100G/H)	Voids - percent K I/I+J	Unit Wt. Total Mix L G×62.4	Stability - lb Measured M	Stability - lb Converted N	Flow O
1 A		2 1/2	1241	712	529	2.35						1710	1710	15
B		2 1/4	1089	630	459	2.37						1780	2120	16
C		2.0	958	557	401	2.39						1350	1990	16
2 A		2 1/4	1019	583	436	2.34						1420	1690	12
B		2.0	1075	619	456	2.36						1540	2260	14
C		2.0	919	535	384	2.39						1440	2120	16
3 A		2 1/6	984	567	417	2.37						1330	1850	12
B		2.0	957	545	412	2.32						1110	1630	12
C		1 13/16	906	519	387	2.35						1020	1830	12
4 A		1 7/8	864	490	374	2.31						800	1340	10
				Avg.		2.36	2.44		4.0	78	147		1845	13
	1-A Mix N. Y. State													
1 A		2 7/16	1159	673	486	2.39						1550	1610	12
B		2 7/16	1165	679	486	2.40						1540	1600	12

Computed by: | Checked by:

AGGREGATES & MIXTURES
District #2

Eastern Rock Products Company   404 Court Street, Utica, New York

PROJECT

SOURCE OR LOCATION OF SAMPLE Prospect, New York DATE RECEIVED 7/3/62

TAKEN BY W. Byrd LaPrade

REPORTED TO   DATE REPORTED

ANALYSIS

Laboratory No.	1-AC Mix					
Sample No.	100% Artificial Sand					
Class Aggregate	Sp. Gr. 2.69					
Passing 1	100.0					
" 1/2	99.7					
" 1/4	99.4					
" 1/8	55.0					
" 20	15.5					
" 80	9.7					
" 200	6.3					
"						
"						
% of Bitumen	6.7					
Marshall Stability	1630	Probable error ± 50#				
Flow	12					
Loss by Decantation						
Specific Gravity	2.31					
Percent Voids	4.6					
Percent Voids filled	77					
Weight Per Cu. Ft.	144					
Solution						

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Specimen No. A	Asphalt Cement % B	Thickness in C	Wt. - Grams In Air D	Wt. - Grams In Water E	Vol. F (D-E)	Sp. Gr. Act. G D/F	Sp. Gr. Theo. H *	AC by Vol. - % I BG/Sp.Gr. of AC	Voids - percent J 100-100G/H	Voids - percent K I/I+J	Unit Wt. Total Mix L G×62.4	Stability - lb Measured M	Stability - lb Converted N	Flow O
1 A		2 1/4	1069	618	451	2.37						1610	1920	12
B		2 3/16	1053	604	449	2.35						1500	1880	12
C		2 1/4	1041	598	444	2.35						1450	1730	12
2 A		2 3/8	1098	625	473	2.33						1350	1470	11
B		2 1/2	1172	662	510	2.30						1700	1700	12
C		2 3/8	1115	634	481	2.32						1660	1710	12
3 A		2 1/2	1172	666	506	2.32						1480	1480	13
B		2 5/16	1043	594	449	2.32						1180	1350	13
C		2 3/16	1016	580	436	2.33						1420	1780	11
4 A		2 3/8	1111	625	486	2.29						1350	1470	12
B		2 3/16	1025	578	447	2.29						1210	1510	12
C		2 9/16	1213	684	529	2.29						1620	1550	13
				Avg.		2.31	2.42		4.6	76.8	144		1630	12

Computed by: | Checked by:

AGGREGATES & MIXTURES

District #2

Eastern Rock Products Company 404 Court Street, Utica, New York

PROJECT

SOURCE OR LOCATION OF SAMPLE Fort Herkimer, N.Y. DATE RECEIVED 7/3/62

TAKEN BY W. Byrd LaPrade

REPORTED TO DATE REPORTED

ANALYSIS

Laboratory No.	1-AC Mix N. Y. State					
Sample No.	Sp. Gr. Aggregate 2.69					
Class Aggregate	Class B Sand, Sp. Gr. 2.67					
Passing 1 %	100.0					
" 1/2	93.8					
" 1/4	87.8					
" 1/8	55.5					
" 20	29.1	50% Artificial Sand				
" 80	9.0					
" 200	4.9					
"						
"						
% of Bitumen	6.2					
Marshall Stability	2100	Probable error ± 50#				
Flow	17					
Loss by Decantation						
Specific Gravity	2.40					
Percent Voids	1.8					
Percent Voids filled	89					
Weight Per Cu. Ft.	150					
Moisture						

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Specimen No. A	Asphalt Cement % B	Thickness in C	Wt. - Grams IN AIR D	Wt. - Grams IN WATER E	Vol. F (D-E)	Sp. Gr. Act. G D/F	Sp. Gr. Theo. H *	AC by Vol. - % I BG/Sp.Gr. of AC	Voids - percent J (100-100G/H)	Voids - percent K I/I+J	Unit Wt. Total Mix L G×62.4	Stability - lb. Measured M	Stability - lb. Converted N	Flow O
1 A		2 1/2	1201	699	502	2.40						1950	1950	18
B		2 5/8	1292	752	540	2.40						2370	2120	18
C		2 3/8	1166	682	484	2.40						2140	2320	23
2 A		2 1/2	1225	712	513	2.39						2300	2300	16
B		2 7/16	1165	681	484	2.41						2190	2280	18
C		2 9/16	1259	735	524	2.40						2520	2420	18
3 A		2 7/16	1172	684	488	2.40						2330	2410	19
B		2 1/2	1177	686	491	2.40						1950	1950	18
C		2 1/8	1025	597	428	2.40						1640	2170	18
4 A		2 7/16	1172	679	493	2.38						1850	1930	15
B		2 1/4	1091	633	458	2.39						1410	1680	18
C		2 1/8	1022	593	429	2.39						1260	1670	18
				Avg.		2.40	2.45		1.8	89	150		2100	17

Computed by: | Checked by:

AGGREGATES & MIXTURES

District #2

Eastern Rock Products Company 404 Court Street, Utica, N. Y.

PROJECT

SOURCE OR LOCATION OF SAMPLE Oriskany Falls, N.Y. DATE RECEIVED 7/2/62

TAKEN BY W. Byrd LaFrade

REPORTED TO DATE REPORTED

ANALYSIS

Laboratory No.	1-A Mix					
Sample No.	Class B Sand					
Class Aggregate	Sp. Gr. Agg. 2.69					
	Sp. Gr. Sand 2.67					
Passing 1 %	100.0					
" 1/2	99.4					
" 1/4	77.3					
" 1/8	47.4					
" 20	22.0	50% Artificial Sand				
" 80	6.7					
" 200	3.8					
"						
"						
% of Bitumen	6.3					
Marshall Stability	1510	Probable error 35#				
Flow	17					
Loss by Decantation						
Specific Gravity	2.38					
Percent Voids	2.3					
Percent Voids Filled	86.5					
Weight Per Cu. Ft.	148.5					
Moisture						

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Specimen No.	Asphalt Cement %	Thickness in	Wt. - Grams IN AIR	IN WATER	Vol.	Sp. Gr. Act.	Theo.	AC by Vol. %	Voids - percent		Unit Wt. Total Mix	Stability - lb Measured	Converted	Flow
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
					(D-E)	D/F	*	BG/SpGr. of AC	100-100G/H	I/I+J	G x 62.4			
1 A		2 5/8	1248	723	525	2.38						~~1380~~	~~1280~~	~~17~~
B		2 1/2	1181	683	498	2.37						1420	1420	18
C		2 1/4	1052	612	440	2.39						1450	1730	16
2 A		2 1/4	1062	617	445	2.39						1340	1600	13
B		2 3/4	1342	781	561	2.39						2050	1760	17
C		2 3/16	1053	614	439	2.40						1410	1760	12
3 A		2 3/8	1141	663	478	2.39						1440	1570	13
B		2 3/8	1121	648	473	2.37						1250	1360	14
C		2 1/8	997	575	422	2.37						1180	1560	13
4 A		2 1/4	1080	623	457	2.37						1370	1630	12
B		2 3/8	1123	647	476	2.36						1150	1250	14
C		2 1/16	973	563	410	2.38						0870	1210	14
				Avg.		2.38			2.3	86.5	148.5		1510	14

Computed by: | Checked by:

AGGREGATES & MIXTURES
District #2

Eastern Rock
PROJECT

SOURCE OR LOCATION Oriskany Falls,
New York

TAKEN BY W. Byrd LaPrade

DATE RECEIVED 7/2/62

REPORTED TO

DATE REPORTED

ANALYSIS

Laboratory No.	1-AC armor coat		New York State			
Class Aggregate	50% Natural Sand		Class B Sand		Sp. Gr. agg. 2.69	
Passing %					Sp. Gr. Sand 2.67	
" 1						
" 1/2	100.0					
" 1/4	75.2					
" 1/8	46.0					
" 20	27.2					
" 40	16.4	50% Artificial Sand				
" 80	8.0					
" 200	3.9					
Penetration						
Average Penetration					Average	
% of Bitumen	7.3				Average	
Marshall Stability	1800	Flow	19	Probable error ± 55#		
Specific Gravity	2.39					
Percent Voids	.5%					
Percent Voids filled	97%					
Weight per cu. ft	149					
Moisture in subbase						

REMARKS:

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Specimen No. A	Asphalt Cement % B	Thickness in C	Wt. - Grams IN AIR D	Wt. - Grams IN WATER E	Vol. F (D-E)	Sp. Gr. Act. G D/F	Sp. Gr. Theo. H *	AC by Vol. - % I BG/SpGr. of AC	Voids - percent J (100-100G/H)	Voids - percent K I/I+J	Unit Wt. Total Mix L G×62.4	Stability - lb. Measured M	Stability - lb. Converted N	Flow O
1 A		2 9/16	1138	663	475	2.40						1750	1680	22
B		2 7/16	1178	687	491	2.40						1960	2040	20
C		2 7/16	1179	689	490	2.41						2120	2200	22
2 A		2 5/16	1120	654	466	2.40						1930	2200	21
B		2 1/2	1220	709	511	2.39						1750	1750	20
C		2 1/4	1041	608	433	2.40						1760	2210	22
3 A		2 3/16	1044	605	439	2.38						1440	1800	16
B		2 1/8	1033	600	433	2.39						1160	1530	18
C		2 1/8	1018	593	425	2.40						1270	1680	18
4 A		2 1/4	1058	611	447	2.37						1080	1290	17
B		2 1/4	1069	620	449	2.38						1450	1730	18
C		2 1/4	1042	602	450	2.37						1210	1440	18
				Avg.		2.39	2.40		.5%	97	149		1800	19

Computed by: | Checked by:

AGGREGATES & MIXTURES

District #4

Rochester Asphalt Materials, Inc.

PROJECT

SOURCE OR LOCATION OF SAMPLE Penfield, New York DATE RECEIVED 8/16/62

TAKEN BY W. Byrd LaPrade

REPORTED TO DATE REPORTED

ANALYSIS

Laboratory No.	1-A Mix					
Sample No.				Sp. Gr. Agg. 2.66		
Class Aggregate				Sp. Gr. Sand 2.66		
Passing				50% Bank Sand		
" 1/2	100.0		31.3	50% Crushed Dolomite		
" 1/4	68.7		31.2	Sand		
" 1/8	37.5		17.8			
" 20	19.7		9.4			
" 80	10.3		6.7			
" 200	3.6		3.6			
"						
"						
% of Bitumen	6.7					
Marshall Stability	1664					
Flow	24					
Loss by Decantation						
Specific Gravity	2.46					
Percent Voids	1.2					
Percent Voids filled	94					
Weight Per Cu. Ft.	153.5					
Moisture						

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Specimen No.	Asphalt Cement %	Thickness in	Wt. - Grams IN AIR	Wt. - Grams IN WATER	Vol.	Sp. Gr. Act.	Sp. Gr. Theo.	AC by Vol. - %	Voids - percent	Voids - percent	Unit Wt. Total Mix	Stability - lb. Measured	Stability - lb. Converted	Flow
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
					(D-E)	D/F	*	BG/SpGr. of AC	(100-100 G/H)	I/I+J	G×62.4			
1 A MIX N. Y. STATE														
1 A		2 1/2	1253	741	512	2.45						1700	1700	22
B		2 9/16	1319	784	535	2.46		.96				1760	1690	24
C		2 9/16	1319	784	512	2.46		.96				1860	1765	26
2 A		2 9/16	1265	752	512	2.47		.96				1540	1480	24
B		2 9/16	1262	751	511	2.47		.96				1750	1680	28
C		2 5/16	1158	688	470	2.47		1.14				1440	1640	22
				Avg.		2.46	2.48		1.2	94	153.5		1665	24

Computed by: | Checked by:

AGGREGATES & MIXTURES

J. P. Baker, Supt.
Bituminous Products, Inc.
Plant #1, 500 Como Park Boulevard
PROJECT

SOURCE OR LOCATION OF SAMPLE Buffalo 25, New York DATE RECEIVED

TAKEN BY W. Byrd LaPrade

REPORTED TO DATE REPORTED

ANALYSIS

Laboratory No.	1-A Mix	New York State				
Sample No.	Sand from Buffalo Slag Sp. Gr. Stone 2.69					
Class Aggregate						
	1-A			1-AC		
Passing %			50% blend Natural Sand Franklinville Plant			
" 1/2	100.0			100.0		
" 1/4	78.4			98.0		
" 1/8	45.8			57.0		
" 20	19.0			30.1		
" 80	8.9			10.7		
" 200	5.0			6.1		
"						
"						
% of Bitumen	7.0±			7.0 ±		
Marshall Stability	1468			1715		
Flow	23			19		
Loss by Decantation						
Specific Gravity	2.37			2.35		
Percent Voids	1.7			2.5		
Percent Voids filled	89.5			85.7		
Weight Per Cu. Ft.	148			146.5		
Moisture						

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Specimen No. A	Asphalt Cement % B	Thickness in C	Wt. - Grams IN AIR D	Wt. - Grams IN WATER E	Vol. F (D-E)	Sp. Gr. Act. G D/F	Sp. Gr. Theo. H *	AC by Vol. - % I BG/SpGr. of AC	Voids - percent J (100-100 G/H)	Voids - percent K I/(I+J)	Unit Wt. Total Mix L G×62.4	Stability - lb. Measured M	Stability - lb. Converted N	Flow O
1-A MIX														
1 A		2 5/8	1244	717	527	2.36		.93				1350	1255	20
B		2 9/16	1223	701	521	2.35		.96				1370	1315	22
C		2 5/8	1269	734	535	2.37		.93				1640	1525	24
2 A		2 1/2	1208	700	508	2.37		1.0				1530	1530	26
B		2 9/16	1242	721	520	2.39		.96				1590	1525	24
C		2 3/8	1148	667	480	2.39		1.09				1500	1685	20
3 A		2 1/4	1055	611	443	2.39		1.19				1250	1490	22
B		2 3/8	1118	648	469	2.38		1.09				1300	1415	20
C		2 1/4	1086	628	457	2.37		1.19				1220	1455	24
				Avg.		2.37	2.41		1.7	89.5	148		1468	22.5
1-AC MIX														
1 A		2 1/2	1163	665	498	2.34		1.0				-1500	1500	20
B		2 1/2	1228	704	523	2.34		1.0				1400	1400	20
C		2 7/16	1128	647	480	2.35		1.04				1620	1685	20
2 A		2 3/8	1146	660	485	2.36		1.09				-1840	2000	20
B		2 7/16	1175	676	498	2.35		1.04				1700	1770	18
C		2 3/8	1133	653	480	2.36		1.09				1760	1920	18
				Avg.		2.35	2.41		2.5	85.7	146.5		1715	19

Computed by: | Checked by:

AGGREGATES & MIXTURES

District #6

A. L. Blades & Sons

PROJECT

SOURCE OR LOCATION OF SAMPLE Webb's Crossing
Hornell, New York

DATE RECEIVED 8/8/62

TAKEN BY W. Byrd LaPrade

REPORTED TO

DATE REPORTED

ANALYSIS

Laboratory No.						
Sample No.	1-A State Top					
Class Aggregate	100% Natural Sand					
Passing						
" 1/2	100.0					
" 1/4	81.2					
" 1/8	57.3					
" 20	30.4					
" 80	8.2					
" 200	5.5					
"						
"						
% of Bitumen	6.6					
Marshall Stability	1615					
Flow	14					
Loss by Decantation						
Specific Gravity	2.36					
Percent Voids	2.5					
Percent Voids filled	86					
Weight Per Cu. Ft.	147					
Moisture						

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Specimen No.	Asphalt Cement %	Thickness in	Wt. - Grams IN AIR	Wt. - Grams IN WATER	Vol.	Sp. Gr. Act.	Sp. Gr. Theo.	AC by Vol. - %	Voids - percent	Voids - percent	Unit Wt. Total Mix	Stability - lb. Measured	Stability - lb. Converted	Flow
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
					(D-E)	D/F	*	BG/Sp.Gr. of AC	100-100 G/H	I/I+J	G x 62.4			
1 A		2 3/4	1269	730	539	2.36						1900	1635	15
B		2 11/16	1279	730	549	2.35						1960	1740	15
C		2 3/4	1291	751	540	2.39						1860	1700	18
2 A		2 7/16	1170	673	497	2.36						1520	1580	12
B		2 9/16	1232	708	524	2.35						1690	1620	13
C		2 3/8	1115	641	474	2.35						1300	1420	13
				Avg.		2.36	2.42		2.5	36	147		1615	14

Computed by: | Checked by:

AGGREGATES & MIXTURES

District #7

General Crushed Stone

PROJECT

SOURCE OR LOCATION OF SAMPLE Watertown, New York DATE RECEIVED 8/9/62

TAKEN BY W. Byrd LaPrade

REPORTED TO DATE REPORTED

ANALYSIS

Laboratory No.							
Sample No.	1-AC Armor Coat		New York State				
Class Aggregate							
Passing							
" 1/2	100.0						
" 1/4	95.4						
" 1/8	50.3						
" 20	23.5						
" 80	6.2						
" 200	2.2						
"							
"							
% of Bitumen	.72						
Marshall Stability	1340						
Flow	19						
Loss by Decantation							
Specific Gravity	2.39						
Percent Voids	1.0						
Percent Voids filled	95						
Weight Per Cu. Ft.	149						
Moisture							

COMPUTATION OF PROPERTIES OF ASPHALT MIXTURES

Job No: | Project: | Description of blend: | Date:

Specimen No. A	Asphalt Cement % B	Thickness in C	Wt. – Grams In Air D	Wt. – Grams In Water E	Vol. F (D–E)	Sp. Gr. Act. G D/F	Sp. Gr. Theo. H *	AC by Vol. – % I BG/Sp.Gr. of AC	Voids – percent J (100-100 G/H)	Voids – percent K I/I+J	Unit Wt. Total Mix L G×62.4	Stability – lb Measured M	Stability – lb Converted N	Flow O
1 A		2 1/2	1190.3	691.3	499	2.39						1320	1320	20
B		2 1/2	1152.3	666.0	486	2.37						1220	1220	20
C		2 9/16	1238.4	718	520.4	2.38						1470	1410	18
2 A		2 3/8	1122	651.4	470.6	2.39						1330	1450	18
B		2 3/8	1133	656.2	476.8	2.39						1140	1240	20
C		2 9/16	1220	705.5	514.5	2.38						1460	1400	20
				Avg.		2.39	2.415		1.0	95	149		1340	19

Computed by: | Checked by:

APPENDIX C

Current Literature

SKID RESISTANCE

Skid Resistance.[1] The physical characteristics of aggregates vary considerably; perhaps the hardness factor is the most important. A limestone, being a sedimentary rock, has a hardness of 3 in Mohr's hardness scale. A natural sand, being predominately quartz, will have a hardness of 7. This is quite relevant to the polishing characteristics of the aggregate; and consequently, affects the skid coefficient. Limestone dust can be a problem as it is practically impossible to remove. Although most of this is used as mineral filler, it is difficult to control by percent of mix.

Summary of Skid Coefficient by Major Aggregate Types [2]

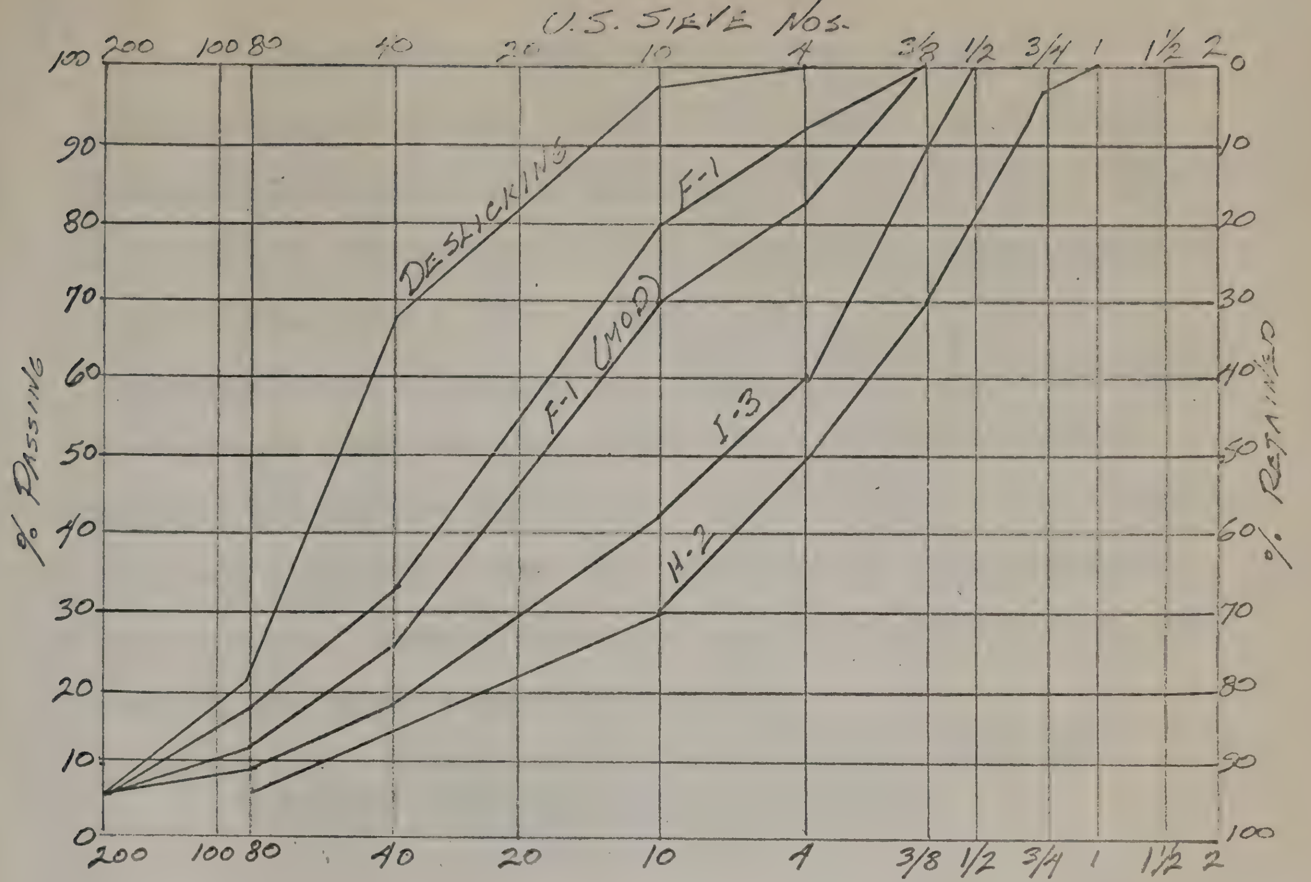
(Pavement Wet, 40 mph)

Aggregate Type	No. of Sources	No. of Sites	Range	Average
Limestone (Dolomite)*	26	1298	.16-.62	.369
Siliceous Gravel*	2	34	.43-.52	.474
Trap Rocks (Diabase)*	2	115	.35-.59	.476
Granites*	4	114	.43-.68	.525
Coarse Sand**	9	270	.46-.72	.573
Fine Sand***	6	106	.53-.85	.674

*As found in I-3 and H-2 mixes or Mixed-in-place treatments.
**As found in F-1 mixes
***As found in deslicking mixes. (See Figure 1).

1 "Relative Skid Resistance of Pavements Surfaces based on Michigan's Experience", by E. A. Finney and M. G. Brown. pg. 439

2 "Further Studies of Skid Resistance of Virginia Pavements", by F. P. Michols, Jr.



SIEVE NO.	H-2 % PASSING	I-3 % PASSING	F-1 (MOD.) % PASSING	F-1 % PASSING	DESLICKIN % PASSING
1"	100				
3/4"	95-100				
1/2"		100			
3/8"	60-80	80-100	100	100	
4	40-60	50-70	75-90	85-100	100
10	20-40	35-50	60-80	65-95	95-100
40		10-25	15-35	20-45	40-95
80	3-10	3-15	5-15	5-30	12-30
200		2-10	2-10	2-10	2-8
APPROX AC.	5.0%	6.2%	7.0%	7.2%	8.0%

Figure 1. Typical Virginia plant mix gradings.

Conclusions drawn from this report are that slippery pavements will develop from aggregates which are susceptible to polishing, regardless of the texture. This was based on the principle that a dense sand paper textured surface will hold a film of water, and high speed traffic tires will have a tendency to aquaplane. On the other hand, a coarse or open mix will allow the heavy rain to drain between the surface aggregate. In 1954 resurfacing contracts required that 50% of the fine aggregate be a non-polishing silica sand. Some of these ran up to 100% silica sand. The results are shown below in Table III.

TABLE III. RESULTS OF STOPPING DISTANCE TESTS ON 1-3 MIXES CONTAINING POLISH-RESISTANT FINE AGGREGATE, LAID IN 1954 (Pavement Wet, 40 mph)

Route	County	Traffic* VPD	% Sand	Stopping Distance, Feet 9 months	24 months	48 months
			0	102	128	101
21	Wythe	1150	20-25	93	135	107
			40-50	99	132	97
			0	123	144	125
33	Rock-ingham	3500	20-25	109	136	107
			40-50	110	126	110

*Average daily traffic fiscal year 1957-58.

As can be seen from Table III, little benefit was gained from adding polish resistant fine aggregate. "The factor which seems to have the greatest effect on slipperiness of wet pavements, then, is the aggregate with which a pavement is built."

As a result of these tests, Virginia will no longer allow the use of limestone or dolomite aggregates in the surface course.

RESULTS OF TRIAL MIXES

[1]In This report by P. A. Wedding & R. D. Gaynor, an overall picture of the affect of aggregate particle shape was investigated. Variations in asphalt content, aggregate grading, percent crushed particles in the coarse aggregate and types of sand (natural or crushed) were analyzed. For our purposes, only the later variation at optimum asphalt content were extracted from the report. Figure 2 shows the gradations used on these trial mixes. Quartzite gravel was used for natural and crushed aggregate and sand sizes. The apparent specific gravities were the same 2.66 for each size and type. Therefore, particle shape was the only variable here. The results are plotted in Figure 3.

Stability. Stability was substantially higher for the crushed sand condition and not too high to produce a semi-rigid condition. This is significant in that the densities are generally lower for the crushed sand. This is an evidence of better keying in the sand sizes.

Void Content. The void content is higher for the natural sands but not significantly so; and only occurs with the 35% sand ratio. This small variation shows little affect between the two sands.

---

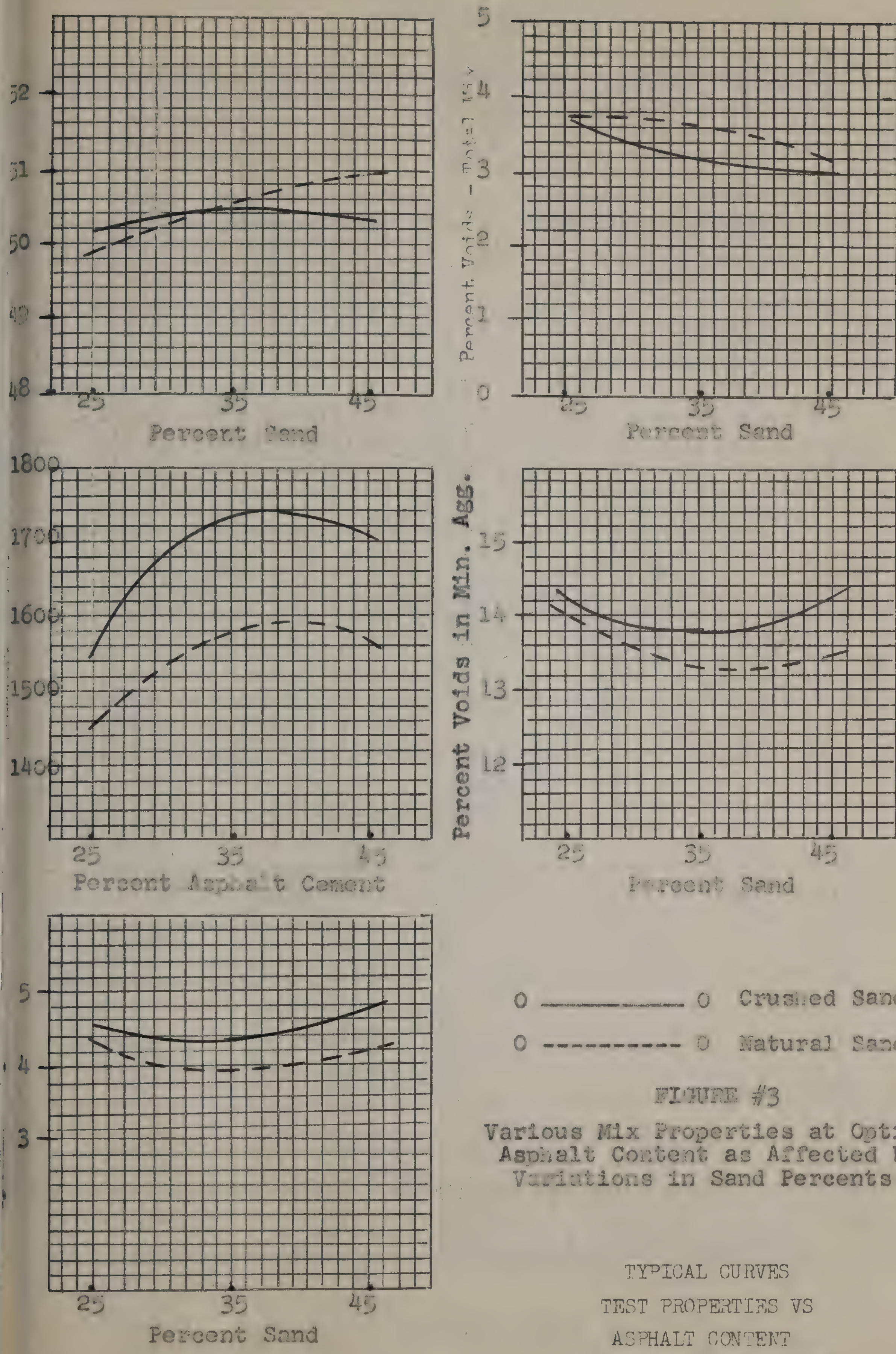
1 "The Effect of Using Crushed Gravel as the Coarse and Fine Aggregate in Dense Graded Bituminous Mixtures", by P. A. Wedding & P. D. Gaynor AAPT Vol. 30, 1961, pg. 469

Unit Weight. The unit weight was not significantly higher for the natural sands which usually runs parallel with Marshall Stability. This similarity in unit weight and difference in Marshall Stability is a very definite comparison of the two sands. The natural sands having the higher unit weight show their ability to compact into a more denser state than the artificial sands. This is related to the particle structure, the natural sands being more rounded will flow more readily than an angular particle. This could be termed a more workable condition.

TABLE VIII SUMMARY OF TEST RESULTS

Average of Values for the Four Percentages of Crushed Gravel Listed in Table IX

Sand Ratio %	Maximum Stability Pounds	Maximum Unit Wt. lb/cu.ft.	Mix Properties at Optimum Asphalt Content: Asphalt %	Stability Pounds	Unit Wt. lb/cu.ft.	Air Voids %	Air Voids Filled %	Flow 1/100"	Agg. Voids
Crushed Sand Mixes									
25	1560	150.2	4.6	1530	150.2	3.8	74	9.9	14.3
35	1770	150.8	4.5	1730	150.2	3.2	75	9.8	13.8
45	1720	150.3	4.3	1710	150.1	3.0	77	9.2	14.4
Natural Sand Mixes									
25	1480	150.4	4.3	1450	149.8	3.8	72	9.3	14.2
35	1680	151.0	4.1	1590	150.5	3.8	72	10.1	13.4
45	1630	151.1	4.4	1550	150.8	3.2	73	9.1	13.5



O ———————— O Crushed Sand

O ---------- O Natural Sand

FIGURE #3

Various Mix Properties at Optimum Asphalt Content as Affected by Variations in Sand Percents

TYPICAL CURVES
TEST PROPERTIES VS
ASPHALT CONTENT
ASPHALTIC CONFERENCE

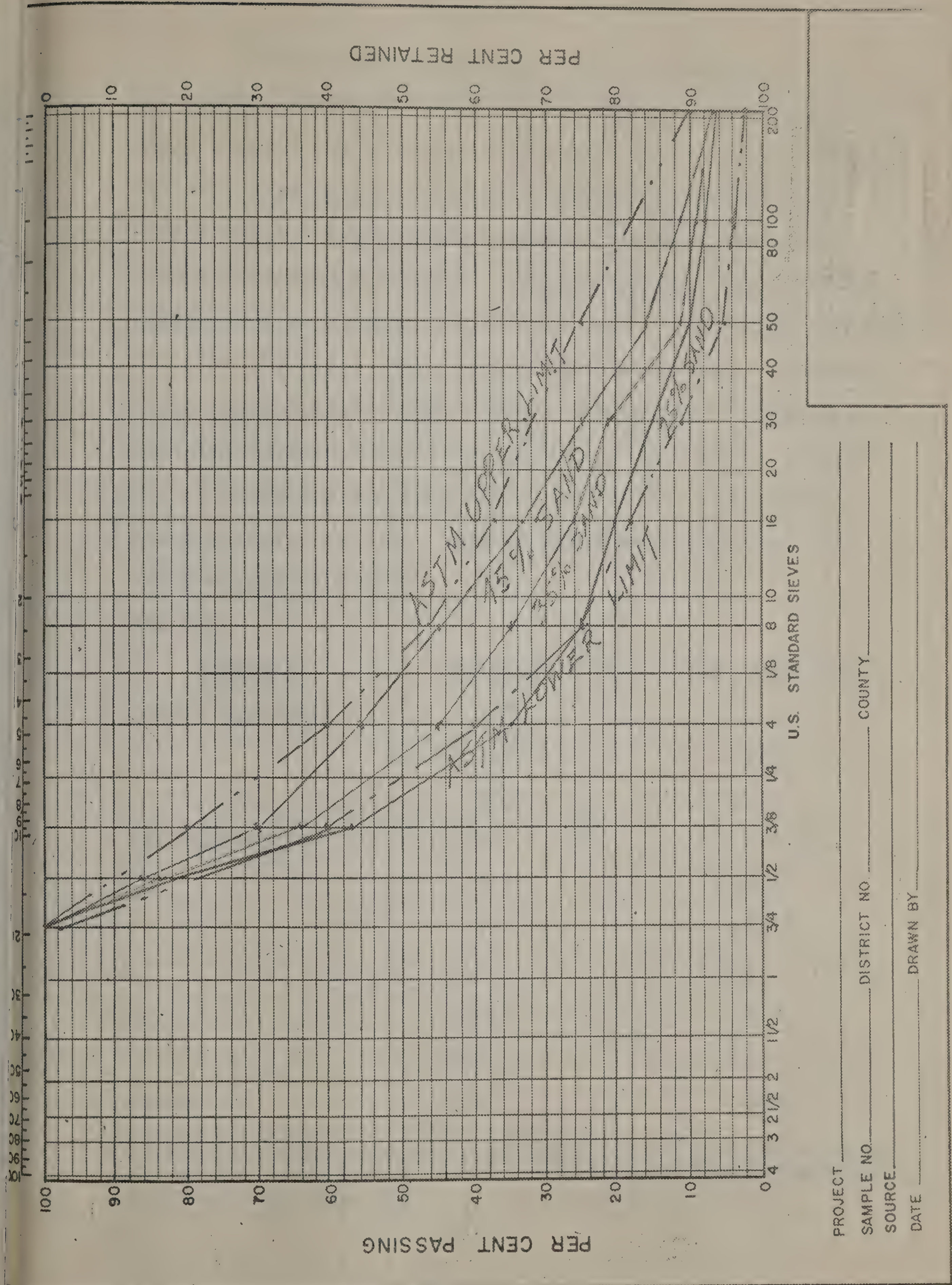

PER CENT RETAINED
PER CENT PASSING
U.S. STANDARD SIEVES
A.S.T.M. UPPER LIMIT
45% SAND
35% SAND
25% SAND
A.S.T.M. LOWER LIMIT
PROJECT
SAMPLE NO.
SOURCE
DATE
DISTRICT NO.
COUNTY
DRAWN BY

FIGURE #2

C-9

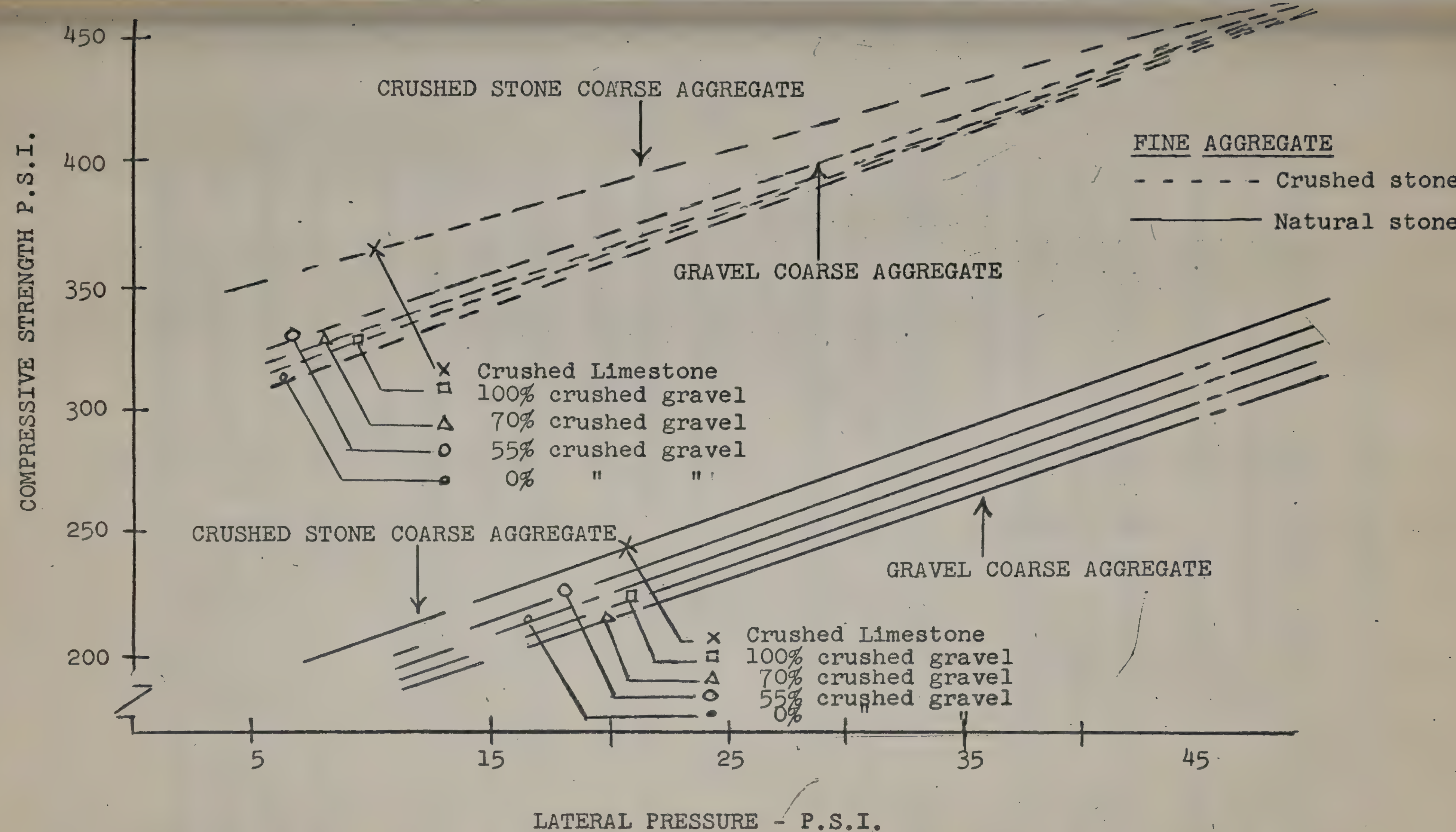
[1]The triaxial-compression method was used to measure the strength of various aggregate and combinations. These results are plotted as straight lines. Mohr's rupture envelope appears to be a curved line with low confining pressures, but practically assumes a straight line at higher confining pressures. For this reason, no confining pressures less than 15 p.s.i. were used. Confining pressures of 15 and 45 p.s.i. were used on the dense mix. Crushed limestone and gravel were used as the aggregates. Natural sand and crushed limestone sand with cement as the mineral filler comprised the fine sizes. A 60 - 70 penetration asphalt cement at 6.0 - 5.5% of total weight was used as optimum asphalt content.

TABLE I

Material	Passing	Dense Grading
Coarse aggregate	3/4"	7.0
	1/2	9.0
	3/8	16.0
Fine aggregate	#4	7.0
	6	6.0
	8	10.0
	16	19.0
	50	9.5
	100	10.0
Cement	200	6.5

[1]"Effect of Aggregate Shape on Stability of Bituminous Mixes", by M. Herrin and W. H. Goetz. Proceedings Highway Research Board, 1954. pg. 298

The crushed stone sand gave compressive strength considerably higher than the natural sands as can be seen from the results of the triaxial test. This type of testing is a function of cohesion and angle of internal friction. It is obvious that these two values would be considerably higher for a rough surface texture than for a smooth rounded surface particle.



EFFECT OF FINE AGGREGATE TYPE ON COMPRESSIVE STRENGTH

DENSE GRADED MIXTURES

C-12

LITERATURE SURVEYED

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2. "Research on Bituminous Pavements Using the Sand Equivalent Test," by R. H. Clough and J. E. Martinez. Highway Research Board Bulletin 300 - Materials for Asphaltic Concrete, 1961. Pages 1-17.

3. "State Practices in the Use of Bituminous Concrete", by W. E. Chastain, Sr., & John E. Burke. Highway Research Board Bulletin 160, Bituminous Paving Mixtures, 1957, Pages 1-107.

4. "A Study of Voids in Asphalt Paving Mixtures", by Leo Kampf and William Ralsch. Proceedings American Asphalt Paving Technologists, Volume 16, 1947; Pages 174-202.

5. "A Study of the Role of Angular Aggregates in the Development of Stability in Bituminous Mixtures", by W. H. Campen & J. R. Smith. Proceedings American Asphalt Paving Technologists, Vol. 17, 1948, Pages 114-142.

6. "Effects of Mixture Coarseness, Mix Temperatures, and Course Thicknesses on Field Density of Bituminous Concrete", by F. M. Williams and F. W. Kimble. Proceedings American Asphalt Paving Technologists, Vol. 23, 1954, Pages 97-118.

7. "The Use of Sand and Gravel in Bituminous Mixtures", by Karl F. Chapel. Proceedings American Asphalt Paving Technologists, Vol. 25, 1956; pages 392-401.

8. "Road Surface Friction From the Standpoint of Automotive and Highway Engineers", by P. C. Skeels, K. A. Stonex & E. A. Finney. Proceedings American Asphalt Paving Technologists, Vol. 25, 1956, Pages 353-378.

9. "Paving the Maine Turnpike", b Charles F. Parker. Proceedings American Asphalt Paving Technologists, Vol. 25, 1956, Pages 292-334.

10. "Recent Investigations of Design of Asphalt Paving Mixtures", by J. Lefebvre. Proceedings American Asphalt Paving Technologists, Vol. 26, 1957, Pages 321-394.

11. "The Effects of Using Crushed Gravel as the Coarse and Fine Aggregate in Dense Graded Bituminous Mixtures", by Presley A. Wedding and Richard D. Gaynor. Proceedings American Asphalt Paving Technologists, Vol. 30, 1961, Pages 469-492.

12. "Stone Quarries - Location and Geologic Characteristics" Engineering Research Series No. RR 59-1, State of New York, Department of Public Works.

13. "Fine Aggregate Sources - Location and Geologic Characteristics" Engineering Research Series, Research Report RR 61-2, State of New York, Department of Public Works.

A TABLE OF APPROVED SOURCES OF FINE AGGREGATES

Public Works Specifications

by Districts

APPROVED SOURCES OF FINE AGGREGATES
Public Works Specifications

DISTRICT 1
Sand

	SOURCE OF MATERIAL			
SUPPLIER - NAME AND ADDRESS	COUNTY	TOWN	SP. GR.	TYPE
Nicholas Pallette Route 9N, Corinth, N. Y.	Saratoga	Corinth	2.67	a
Troy Sand & Gravel Co. P.O. Box 424, Averill Park, N.Y.	Rensselaer	Nassau	2.67	b
Albany Gravel Co. (J. Hopkins) N.Pearl & Loudenville Rd. Albany	Rensselaer	Stephentown	2.70	b
Republic Steel Co. Port Henry, N.Y.	Essex	Moriah	2.73	a
Nicholas Pallette Corinth Rd., Corinth, N.Y.	Saratoga	Corinth	2.72	a
DeLuke Sand & Gr., Co. Amsterdam Rd., Scotia, N.Y.	Schenectady	Glenville	2.60	c
Warren Aggregates Chestertown, N.Y.	Warren	Chester	2.75	a
General Sand & Stone Co. Dalton, Massachusetts	Massachusetts	Dalton	2.69	c
Clark & Haynes Poultney, Vt.	Vermont	Poultney	2.73	b
T.C. Norman (Mayersohn, Lessee) Saranac Lake, N.Y.	Essex	St. Armand	2.67	a
Coxsackie Sand & Gr. Co. Coxsackie, N.Y.	Greene	Coxsackie	2.67	b
Wm. E. Dailey So. Shaftsbury, N.Y.	Vermont	So. Shaftsbury	2.70	c
Hudson Valley S. & St. Co. Mechanicville, N.Y.	Saratoga	Moreau	2.70	a

APPROVED SOURCES OF FINE AGGREGATES
Public Works Specifications

DISTRICT 2
Sand

	SOURCE OF MATERIAL			
SUPPLIER - NAME AND ADDRESS	COUNTY	TOWN	SP. GR.	TYPE
Eastern Rock Products Co. 404 Court St.,Utica, N.Y.	Oneida	Boonville	2.63	b
B. William Delia Northville, N.Y.	Fulton	Northampton	2.72	a
Eastern Rock Products Co. 404 Court St., Utica, N.Y.	Herkimer	Russia	2.63	b
St. Johnsville Supply Co. St. Johnsville, N.Y.	Montgomery	St. Johnsville	2.63	c
Cushing Stone Co. 408 State St., Schenectady, N.Y.	Fulton	Broadalbin	2.66	a
Grace Longstaff - (Material S. & Gr. CO.) Gravesville, N.Y.	Herkimer	Russia	2.63	b

APPROVED SOURCES OF FINE AGGREGATE
Public Works Specifications

DISTRICT 3
Sand

SUPPLIER - NAME AND ADDRESS	SOURCE OF MATERIAL: COUNTY	SOURCE OF MATERIAL: TOWN	SP. GR.	TYPE
J. J. Harrington (Bowen Farm) Auburn, N.Y.	Cayuga	Sennett	2.72	c
J. H. Davies R.D. #2, Oswego, N.Y.	Oswego	Scriba	2.60	b
Rumsey - Ithaca Corp. P.O. Box 17, Ithaca, N.Y.	Tompkins	Ithaca	2.73	c
Bero Construction Co. R.D. #2, Homer, N.Y.	Cortland	Homer	2.63	c
General Crushed Stone Co. Easton, Pa.	Oswego	Sandy Creek	2.60	c
DeWitt Sand & Gr. Co. E. Manlius Rd., E.Syracuse, N.Y.	Onondaga	Clay	2.63	c
W. F. Saunders (A. Serson) P.O. Box 308, Nedrow, N.Y.	Onondaga	Marcellus & Camillus	2.63	c
Massaro Sand & Gr. Co. 207 Erie St., Fulton, N.Y.	Oswego	Volney	2.66	b
Massaro Sand & Gr. Co. 207 Erie St., Fulton, N.Y.	Oswego	Volney	2.59	c
Massaro Sand & Gr. Co. 207 Erie St., Fulton, N.Y.	Oswego	Volney	2.67	c
Misner Farm (Cortland Ready Mix) Box 428, Cortland, N.Y.	Zortland	Homer	2.66	c

APPROVED SOURCES OF FINE AGGREGATES
Public Works Specifications

DISTRICT 4
Sand

	SOURCE OF MATERIAL			
SUPPLIER - NAME AND ADDRESS	COUNTY	TOWN	SP. GR.	TYPE
Monarch Materials, Inc. Pine Hill Road, Spencerport, N.Y.	Monroe	Parma	2.64	c
John Syracusa Malone Road, Victor, N.Y.	Ontario	Victor	2.66	c
Batavia Sand & Gr. Co. Cedar St., Batavia, N.Y.	Genessee	Batavia	2.67	c
B. R. DeWitt Pavilion, N.Y.	Orleans	Shelby	2.67	c
B. R. DeWitt Pavilion, N.Y.	Ontario	Manchester	2.67	c
Ontario S. & Gr. Co. Phelps, N.Y. (R.D.)	Ontario	Phelps	2.63	c
Oak Orchard S. & Gr. Co. Medina, N.Y.	Orleans	Ridgeway	2.59	c
Ingersoll Supply & Equip. Co. 73 Gillette Rd., Spencerport, N.Y.	Monroe	Parma	2.69	c
Dolomite Prod. Co. 1218 Grantie Bldg., Rochester, N.Y.	Monroe	Penfield	2.66	c
Ingersoll Supply & Equip. Co. Spencerport, N.Y.	Monroe	Parma	2.70	c
Frey Sand & Gr. Co. 561 Pavement Rd., Lancaster, N.Y.	Genessee	Alexander	2.70	c
MacKenzie S. & Gr. Co. R.D. #1, Clifton Springs, N.Y.	Ontario	Manchester	2.70	c
Hoadley S. & Gr. Co. Pavilion, N.Y.	Ontario	Victor	2.63	c
J. E. Redman Sand & Gr. Co. Box 84, Brighton Station, N.Y.	Monroe	Penfield	2.63	c

APPROVED SOURCES OF FINE AGGREGATES
Public Works Specifications

DISTRICT 5
Sand

SUPPLIER - NAME AND ADDRESS	SOURCE OF MATERIAL: COUNTY	SOURCE OF MATERIAL: TOWN	SP. GR.	TYPE
Buffalo Graval Corp. 111 Great Arrow Ave., Buffalo, N.Y.	Pennsylvania	N.W. Bar	2.64	b
Gasport S. & Gr. Co. 33 Marrow St., Lockport, N.Y.	Niagara	Lockport	2.62	c
E. F. Lippert & Co. Allegany, N.Y.	Cattaraugus	Allegany	2.67	b
Buffalo Slag Co. Ellicott Sq. Bldg., Buffalo, N.Y.	Cattaraugus	Machias	2.67	c
Upper Allegany S. & Gr. Co. Corydon, Penn.	Cattaraugus	South Valley	2.67	b
Dan Gernatt Gr. Prod. Collins, N.Y.	Erie	Collins	2.67	c
Pine Hill Conc. Mix Corp. 2255 Bailey Ave., Buffalo, N.Y.	Erie	Newstead & Alden	2.70	c
Gravel Products Div. 1 Austin St., Buffalo, N.Y.	Pennsylvania	---	2.62	c
Empire Bldrs. Supply 820 Cedar Ave., Niagara Falls, N.Y.	Pennsylvania	---	2.62	a
Evans Bldrs. Supply Erie Rd., Angola, N.Y.	Chautauqua	Hanover	2.57	b
Work & Silvis Allegany, N.Y.	Cattaraugus	Red House	2.59	b
Olean Gravel Corp. 142 Davis St., Bradford, Pa.	Cattaraugus	Machias	2.67	c
Erie Sand & Gr. Co. Sassafras St., Erie, Pa.	Pennsylvania	---	2.60	b
Pine Hill Conc. Mix Corp. 2255 Bailey Ave., Buffalo, N.Y.	Erie	Newstead	2.66	c
Buffalo Slag Co. Ellicott Sq. Bldg., Buffalo, N.Y.	Cattaraugus	Allegany	2.53	c

APPROVED SOURCES OF FINE AGGREGATES
Public Works Specifications

DISTRICT 6
Sand

	SOURCE OF MATERIAL			
SUPPLIER - NAME AND ADDRESS	COUNTY	TOWN	SP. GR.	TYPE
Bath Sand & Gr. Co. Bath, N.Y.	Steuben	Bath	2.66	c
Dalrymple Gravel & Contg. 101-105 E. Chemung Pl., Elmira, N.Y.	Steuben	Corning	2.63	b
H. E. Bunce Waverly, N.Y.	Tioga	Barton	2.72	c
A. Rhinehart & Sons E. Corning, N.Y.	Steuben	Corning	2.62	b
Central Materials Corp. Box 223, Owego, N.Y.	Tioga	Tioga	2.63	c

APPROVED SOURCES OF FINE AGGREGATES
Public Works Specifications

DISTRICT 7
Sand

SUPPLIER - NAME AND ADDRESS	SOURCE OF MATERIAL		SP. GR.	TYPE
	COUNTY	TOWN		
Rural Hill Sand & Gr. Co. Belleville, N.Y.	Jefferson	Ellisburg	2.70	c
Putnam & Hawley Potsdam, N.Y.	St. Lawrence	Parishville	2.70	c
Republic Steel Corp. Lyon Mt., N.Y.	Clinton	Dannemora	3.00	a
Bero Constr. Co. Morrisonville, N.Y.	Clinton	Schuyler Falls	2.58	a
Colwell Brothers Gifford St., R.D., Watertown	Jefferson	Watertown	2.63	c
Roy D. Allen R.D., Lowville, N.Y.	Lewis	Watson	2.57	a
Louis Paro R.D., Malone, N.Y.	Franklin	Malone	2.59	c
Tomlinson Brothers Rt. 3, Gouverneur, N.Y.	Jefferson	Antwerp	2.63	c
Smith & Brunell 109 Beekman St., Plattsburgh	Clinton	Plattsburgh	2.57	a

APPROVED SOURCES OF FINE AGGREGATES
Public Works Specifications

DISTRICT 8
Sand

	SOURCES OF MATERIALS			
SUPPLIER - NAME AND ADDRESS	COUNTY	TOWN	SP. GRR	TYPE
Fishkill Builders Supply 248 Broadway, Newburgh, N.Y.	Dutchess	Fishkill	2.66	b
F. H. Stickles & Son Livingston, N.Y.	Columbia	Livingston	2.63	b
Dallenbach S. & Gr. Co. Milltown, N.J.	New Jersey	4-5 miles S.E. of N. Brunswick, N.J.	2.64	a
Ward Pavements Haverstraw, N.Y.	Rockland	Haverstraw	2.67	a
Peekskill Masons Supply Co. Central Ave., Peekskill, N.Y.	Westchester	Cortlandt	2.70	a
Dutchess Quarry & Supply Co. Box 773, Poughkeepsie, N.Y.	Dutchess	Washington	2.67	b
Mountain Sand & Gr. Co. Great Barrington, Mass.	Massachusetts	Gr. Barrington	2.63	c
Columbia Sand & Gr. Co. Martindale Depot, N.Y.	Columbia	Claverack	2.70	c
New York Trap Rock Corp. W. Nyack, N.Y.	Dutchess	Poughkeepsie	2.82	c
Amenia S. & Gr. Co. Box 17, Amenia, N.Y.	Dutchess	Amenia	2.75	c
New York Trap Rock Corp. W. Nyack, N.Y.	Rockland	Haverstraw	2.84	c
Cooney Bros., Inc. Box 365, Tarrytown, N.Y.	Westchester	Cortlandt	2.73	a
Camarco Cont'g. Co. Carmel, N.Y.	Westchester	Somers	2.63	a
Berkshire Gravel Corp. 1277, E.St., Pittsfield, Mass.	Massachusetts	Lenox Dale	2.70	c
Berkshire Gravel Corp. 1277 E.St.,Pittsfield, Mass.	Massachusetts	Pittsfield	2.63	a

APPROVED SOURCES OF FINE AGGREGATES
Public Works Specifications

DISTRICT 8 (cont.)
Sand

	SOURCE OF MATERIAL			
SUPPLIER - NAME AND ADDRESS	COUNTY	TOWN	SP. GR.	TYPE
Stateline S. & Gr. Co. Box 596, Canaan, Conn.	Connecticut	N. Canaan	2.63	a
Sam Braen & Co. Franklin Tpke., Mahwah, N.J.	New Jersey	Hohokus, N.J.	2.60	a
McKee Brothers Rt. #17, Ramsey, N.J.	New Jersey	Hohokus, N.J.	2.70	a
F. J. Melito & Co. 12 Woodcliff Ave., Poughkeepsie, N.Y.	Dutchess	Poughkeepsie	2.67	c
Francis Ryan, Inc. Pleasant Ridge Road, Poughkeepsie, N.Y.	Dutchess	Beekman	2.66	c

APPROVED SOURCES OF FINE AGGREGATES
Public Works Specifications

DISTRICT 9
Sand

	SOURCES OF MATERIALS			
SUPPLIER - NAME AND ADDRESS	COUNTY	TOWN	SP. GR.	TYPE
Bundy Conc. Prod. Co. Sherburne, N.Y.	Chenango	Sherburne	2.63	c
Amos Rogers (Contr. S. & G. Co.) R.D. #1, Moscow, Pa.	Pennsylvania	Madison	2.70	c
Barney & Dickenson, Inc. R.D. #1, Vestal, N.Y.	Broome	Union	2.62	c
B & B Transmix Greene, N.Y.	Chenango	Greene	2.67	c
Sullivan Hwy. Prod. Summitville, N.Y.	Sullivan	Mamakating	2.58	b

APPROVED SOURCES OF FINE AGGREGATES
Public Works Specifications

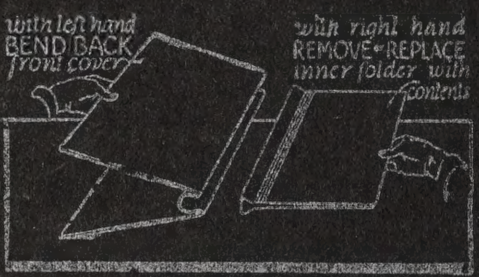
DISTRICT 10
Sand

	SOURCE OF MATERIAL			
SUPPLIER - NAME AND ADDRESS	COUNTY	TOWN	SP. GR.	TYPE
Wivchar S. & Gr. Co. Calverton, N.Y.	Suffolk	Brookhaven	2.66	a
Herbert Sand Co. P.O. Box 3, Milltown, N.J.	New Jersey	E. Brunswick	2.66	a
Preferred S. Shore Plant Hicksville, N.Y.	Suffolk	Islip	2.66	a
Deer Park S. & Gr. Co. Deer Park, N.Y.	Suffolk	Islip	2.66	a
Roanoke S. & Gr. Co. Box 461, Riverhead, N.Y.	Suffolk	Brookhaven	2.63	a
Raritan River Sand Co. Nixon, N.J.	New Jersey	Middlesex, N.J.	2.63	a
Eastern S. & Gr. Co. Miller Place Rd., Middle Island	Suffolk	Brookhaven	2.69	a
Pine Hollow P.O. Box 60, Oyster Bay, N.Y.	Nassau	Oyster Bay	2.66	b
Coram S. & Gr. Co. Coram, N.Y.	Suffolk	Brookhaven	2.69	a
Allen Wood Steel Co. Mine Hill, N.J.	New Jersey	Dover	2.80	a
McCormack S. & Gr. Co. 500 Fifth Ave., N.Y. City, N.Y.	Nassau	No. Hempstead	2.70	a
East Coast Lumber Term. Farmingdale, N.Y.	Suffolk	Babylon	2.64	a
Fehr Sand & Gr. Co. Oyster Bay, N.Y.	Nassau	Oyster Bay	2.60	a
Colonial Sand & Gr. Co. 1740 Broadway, N.Y. City, N.Y.	Nassau	No. Hempstead	2.60	a

APPROVED SOURCES OF FINE AGGREGATES
Public Works Specifications

DISTRICT 10 (cont.)
Sand

SUPPLIER - NAME AND ADDRESS	SOURCE OF MATERIAL		SP. GR.	TYPE
	COUNTY	TOWN		
Eastern Suffolk Conc. & Asph. 32-17 Lawrence St., Flushing	Suffolk	Southampton	2.59	a
Colonial (Metro) S. & Gr. Co. 1740 Broadway, N.Y. City, N.Y.	Nassau	No. Hempstead	2.60	a
J. R. Steers Huntington, N.Y.	Suffolk	Huntington	2.60	a
Approved S. & Gr. Co. 344 Duffy Ave., Oyster Bay	Nassau	Oyster Bay	2.60	a
Industrial S. & Gr. Co. Box 84, Commack, N.Y.	Suffolk	Smithtown	2.58	a
Consolidated Sand & Gr. Co. R.D. #1 Winding Rd., Hicksville	Suffolk	Huntington	2.58	a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BEND BACK
front cover
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inner folder with
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